Radio Mobile Introduction: RF Coverage Plot

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Communications Academy 2008
April 5, 2008

What is Radio Mobile?

- Radio Mobile is a free and powerful tool for plotting RF patterns and predicting the performance of radio systems
- Using freely available terrain elevation data it can produce grey scale, x-ray and rainbow colored virtual maps
- Can also produce 3-D and stereoscopic views as well as flyby animations
- Background images can be merged with scanned maps, satellite photos and Mapquest maps to produce accurate prediction plots
- Written by VE2DBE

Maxwell’s Equations for time varying electric and magnetic fields in free space

$$\nabla \bullet E = \frac{\rho}{\varepsilon_0}$$

Divergence of electric field is a function of charge density

The Hard Way!!

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

A closed loop of E field lines will exist when the magnetic field varies with time

$$\nabla \bullet B = 0$$

Divergence of magnetic field =0 (closed loops)

$$\nabla \times B = \mu_0 I + \varepsilon_0 \mu_0 \frac{\partial E}{\partial t}$$

A closed loop of B field lines will exist in The presence of a current and/or time varying electric field

(where ρ is the charge density)

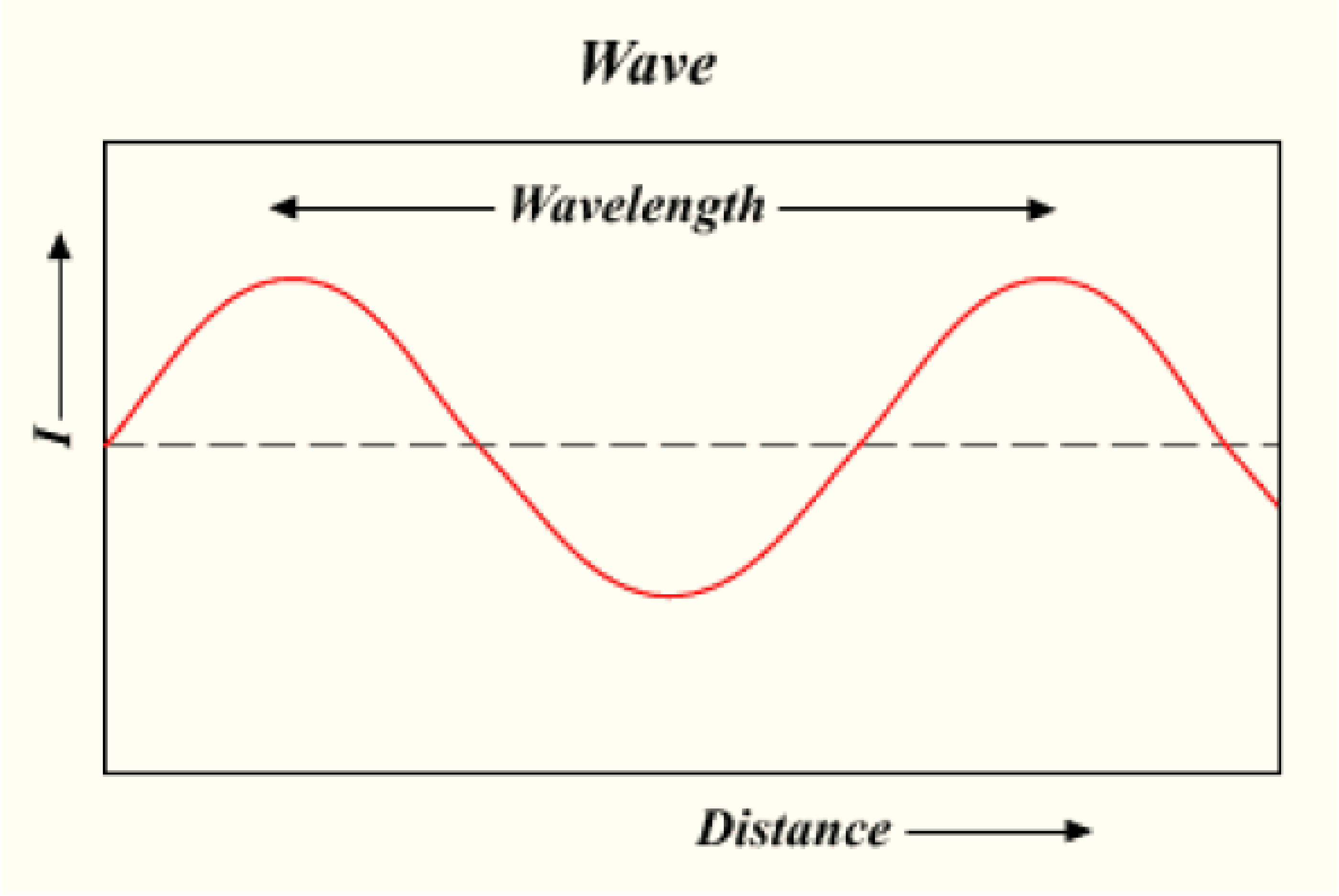
Radio Mobile – The Technology

- Longley-Rice Model
  - aka Irregular Terrain Model
  - U.S. Department of Commerce NTIA/ITS
- Includes most of the relevant propagation modes
  - multiple knife & rounded edge diffraction
  - atmospheric attenuation
  - tropospheric propagation modes (forward scatter etc.)
  - Precipitation
  - diffraction over irregular terrain
  - Polarization
  - specific terrain data
  - atmospheric stratification
  - different climatic regions
  - etc. etc. …

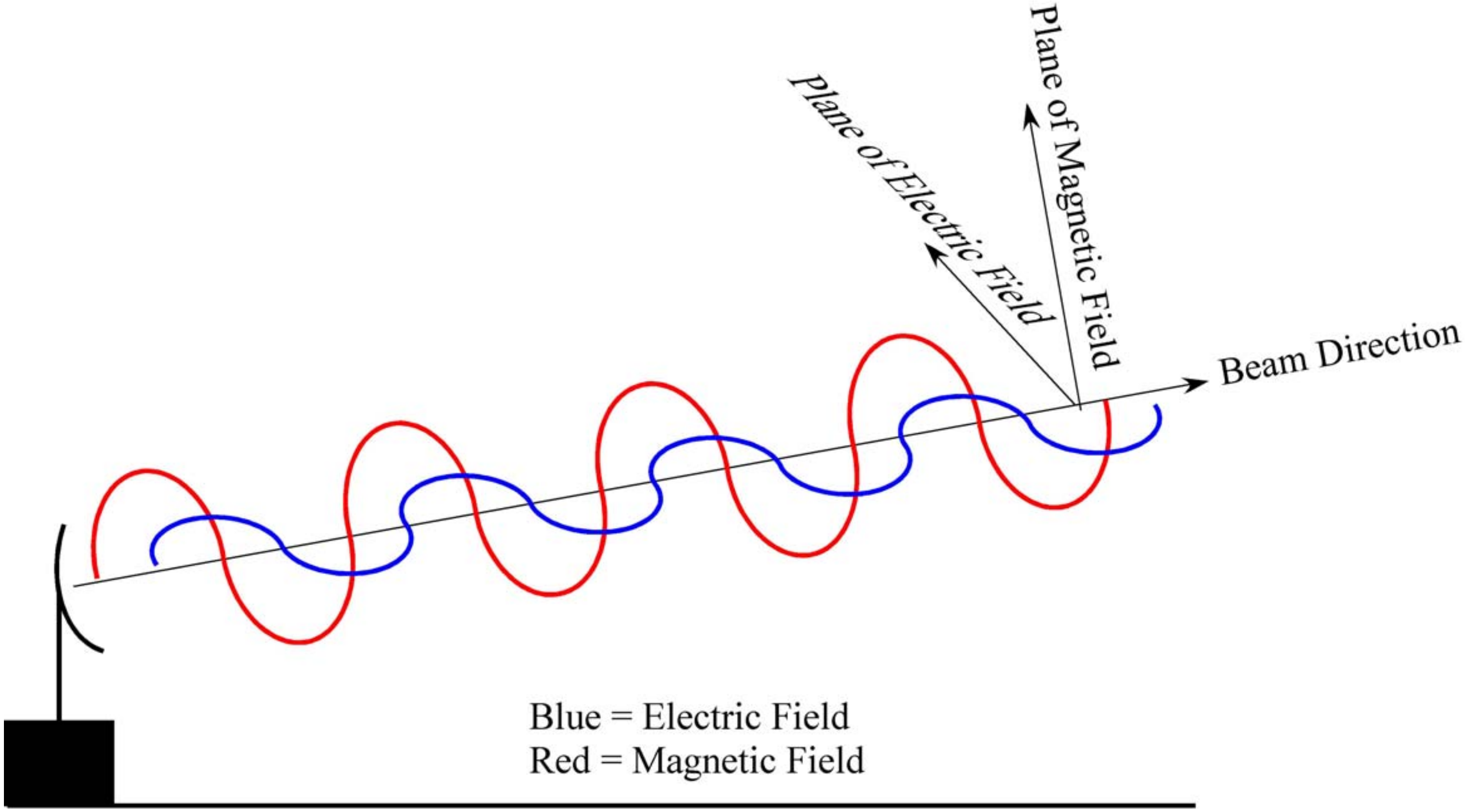
It is only a model!!

- All models have limitations
  - Longley Rice doesn't include ionosphere, so limited applicability at lower frequencies
  - Some skill is needed in choosing the right model for the right circumstances.
  - Accuracy is limited
  - Different models can give different answers
  - May need a statistical interpretation
  - Need good input data (e.g. terrain models)

A Wave



Electromagnetic Waves and Their Propagation Through the Atmosphere

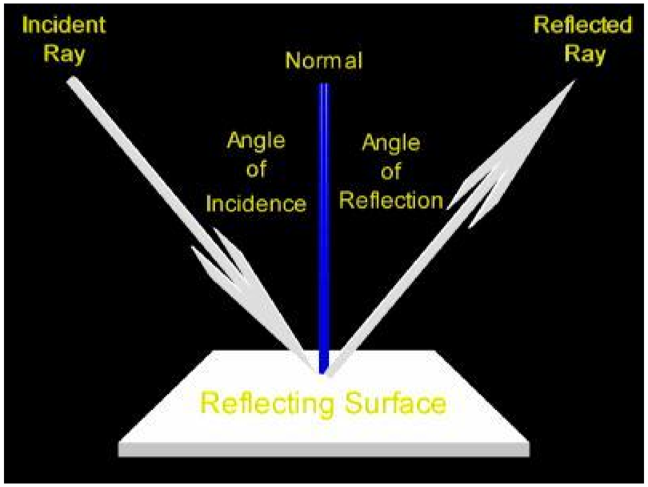


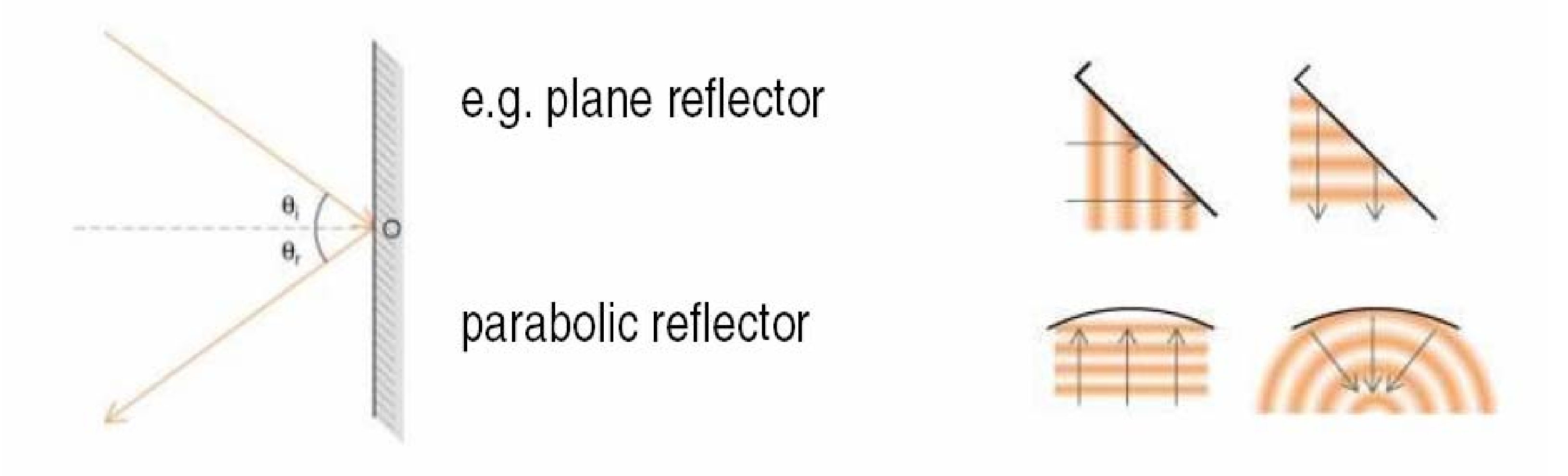
Blue = Electric Field
Red = Magnetic Field

Electromagnetic Waves & Matter..

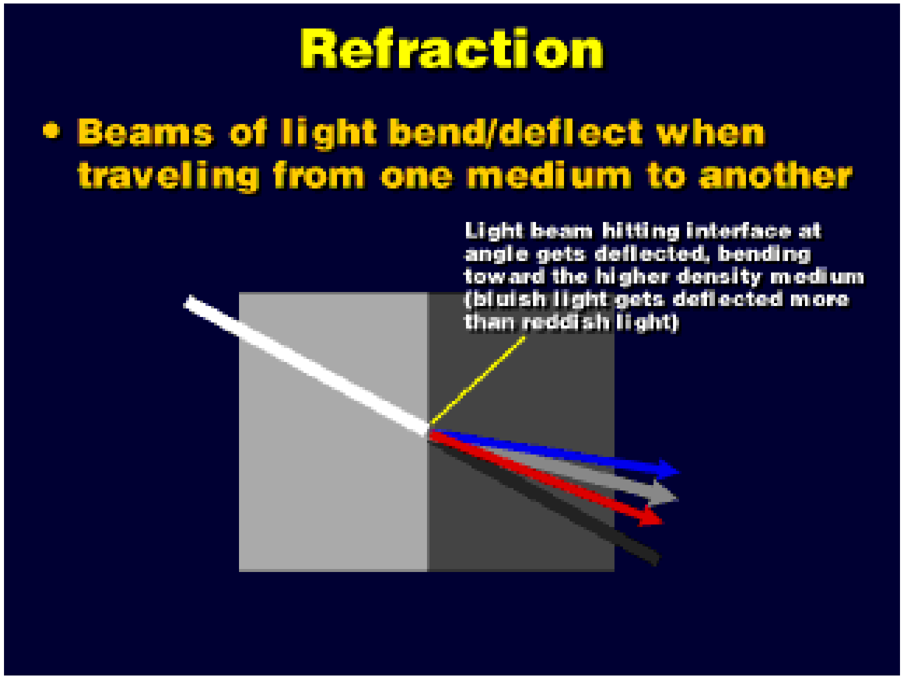
- 4 ways EM waves interact with matter..
  - Reflection
  - Refraction
  - Diffraction
  - Scattering

Reflection


Incident Ray
Normal
Reflected Ray
Angle of Incidence
Angle of Reflection
Reflecting Surface


θ_i
θ_r
O
e.g. plane reflector
parabolic reflector

Refraction

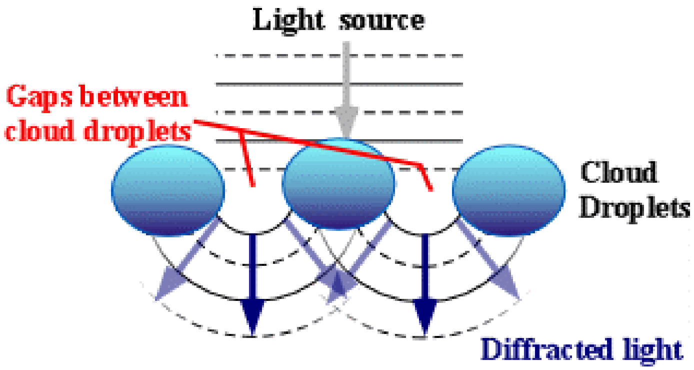


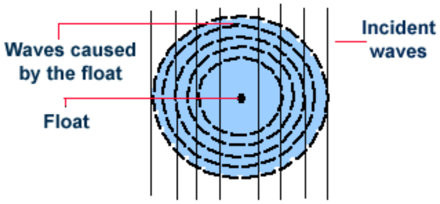
Refraction

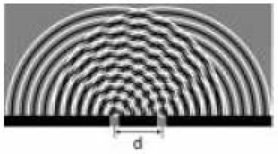
- Beams of light bend/deflect when traveling from one medium to another

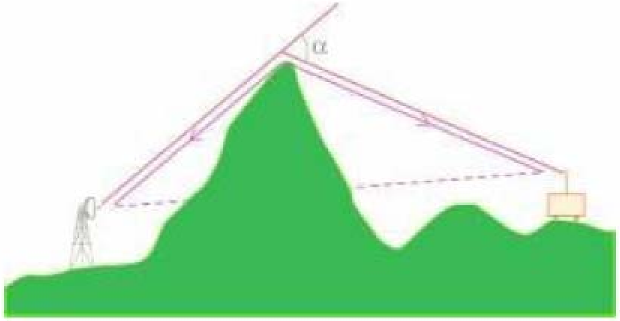
Light beam hitting interface at angle gets deflected, bending toward the higher density medium (bluish light gets deflected more than reddish light)

Diffraction

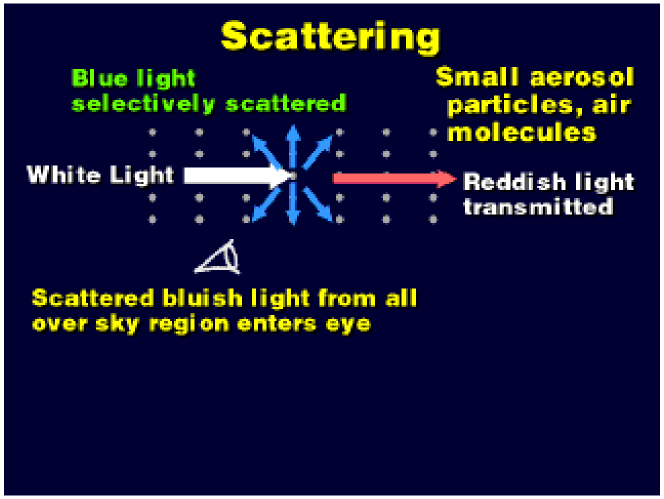








Scattering



Scattering

Blue light selectively scattered

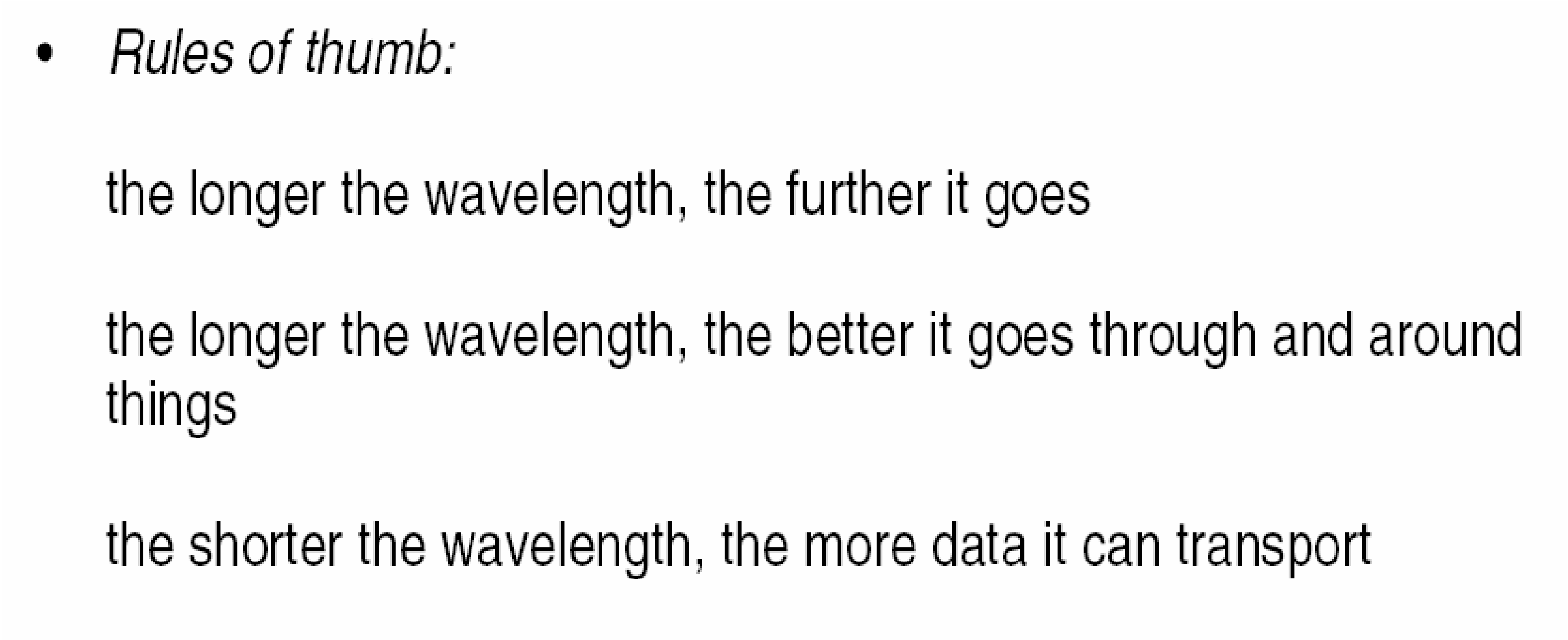
Small aerosol particles, air molecules

White Light

Reddish light transmitted

Scattered bluish light from all over sky region enters eye

Radio Waves Rules of Thumb…



- *Rules of thumb:*

  the longer the wavelength, the further it goes

  the longer the wavelength, the better it goes through and around things

  the shorter the wavelength, the more data it can transport

Radio Propagation in Free Space

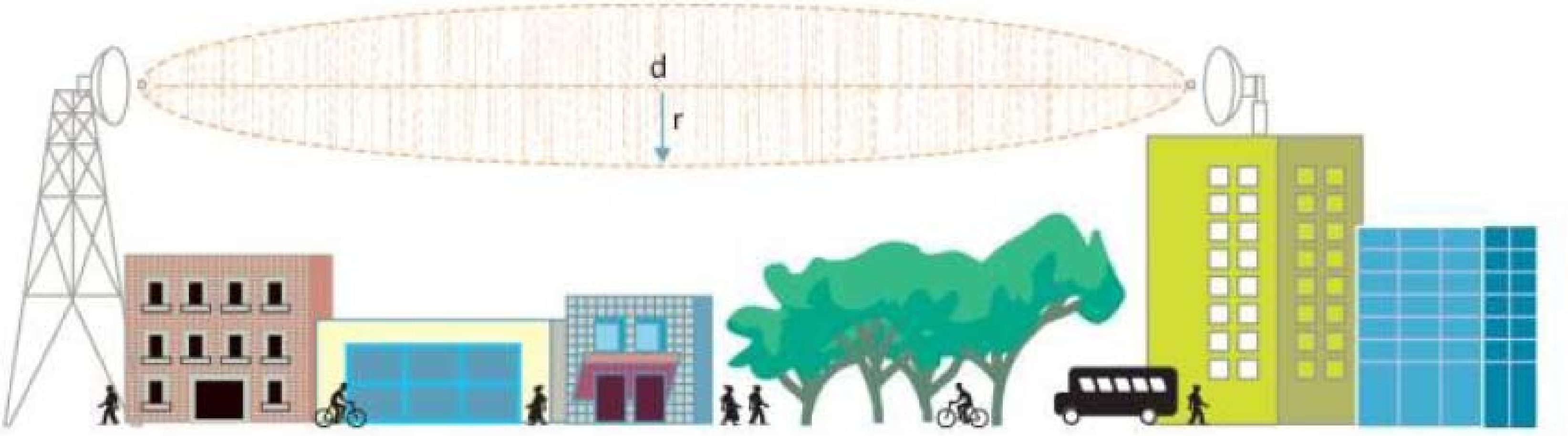
- Free Space Loss (FSL)
- Fresnel Zones
- Line of Sight
- Multipath Effects

Free Space Loss (Friis' Formula)

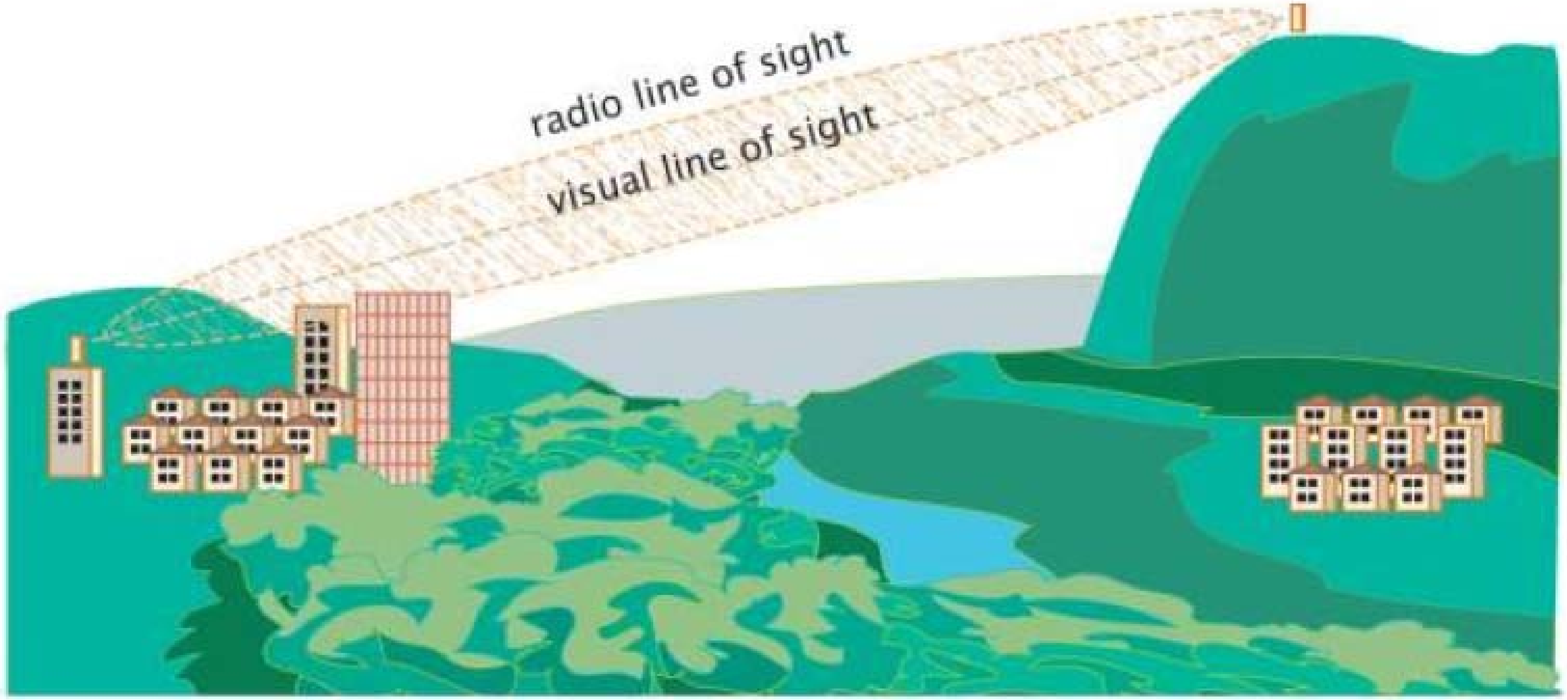
$$L_{fs} = 32.44 + 20\log d + 20\log f - G_T - G_R$$

L_{fs} = free space Loss
d = distance separating transmit and receive antennas
f = frequency
G_T = gain of transmitter antenna
G_R = gain of received antenna

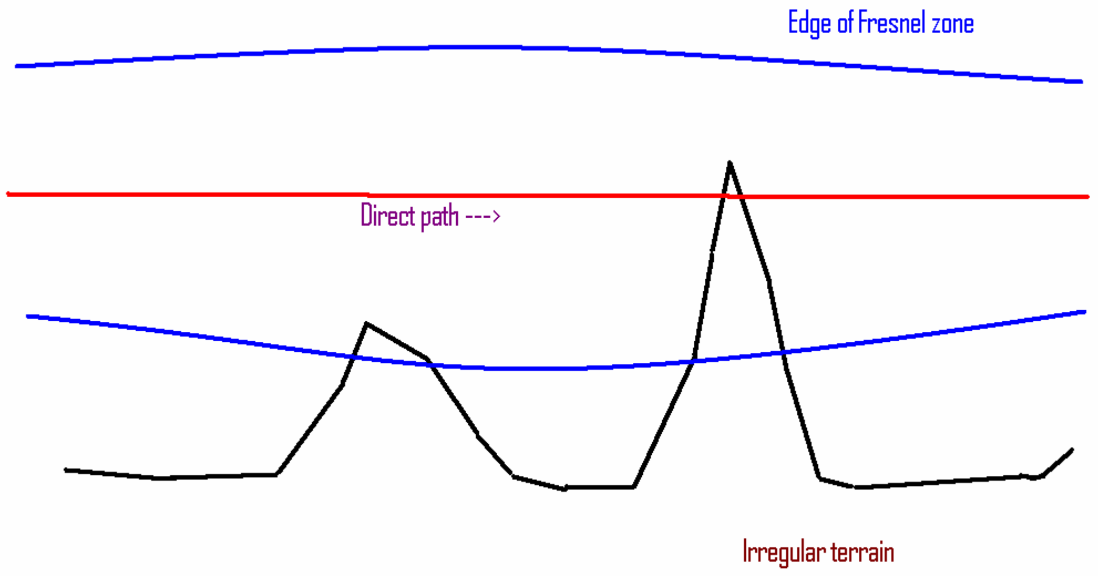
Fresnel Zones



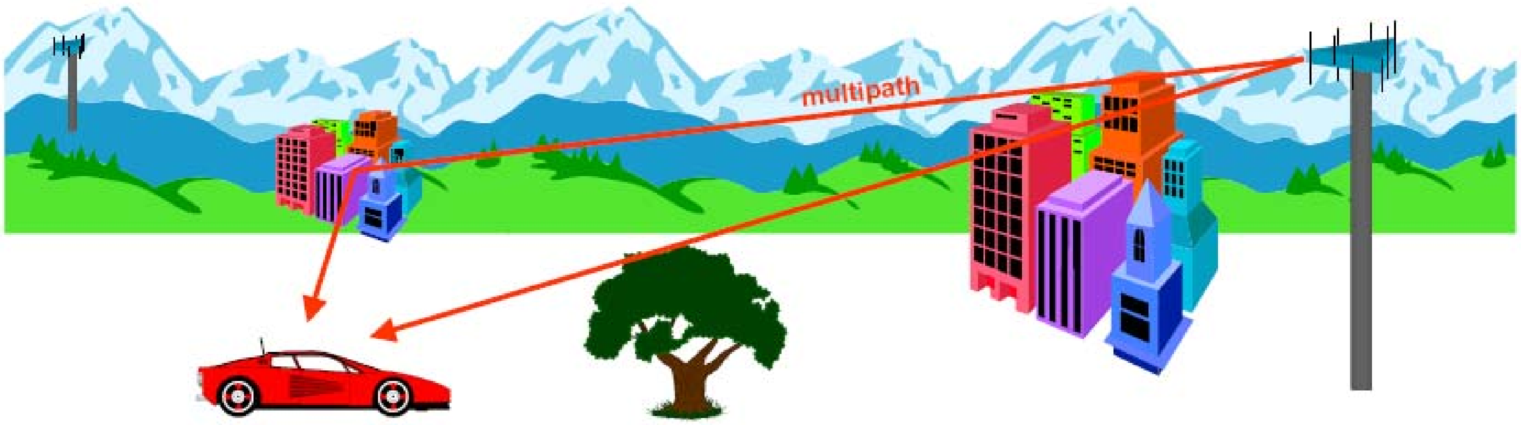
Line of Sight



Is an obstruction obstructing?



UHF Propagation



- Propagation is mostly line-of-sight
- Reflections off conductive objects (buildings, vehicles, fences, etc.) are prevalent
- Refraction around obstacles is possible

The Mobile Radio Propagation Channel

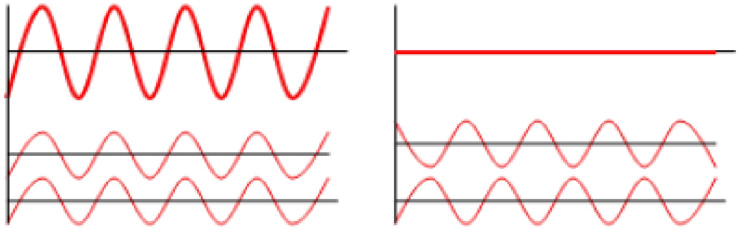
Amplitude

Frequ

A wireless channel exhibits severe fluctuations for small displacements of the antenna or small carrier frequency offsets

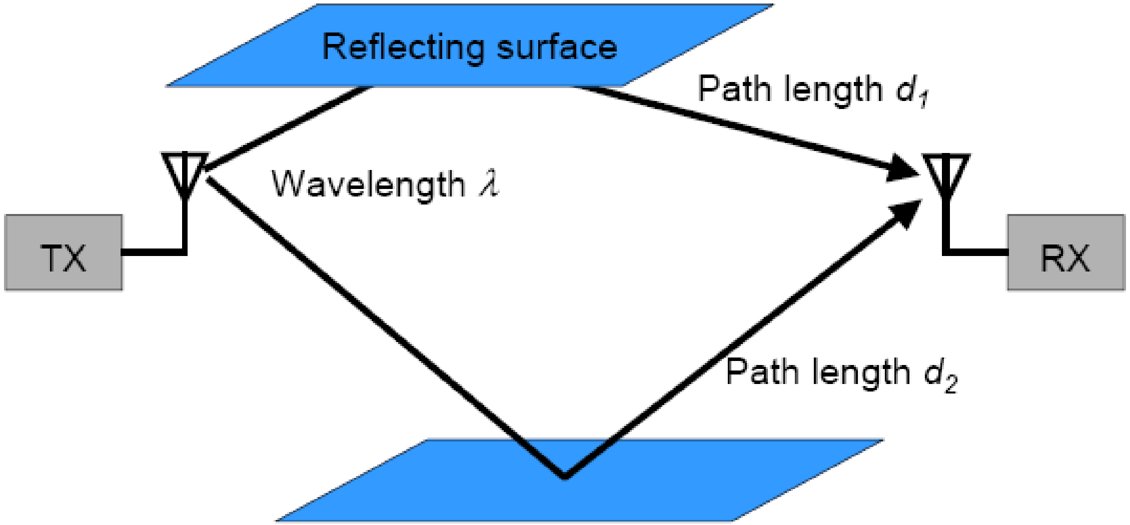
Interference

- Waves can annihilate each other, so that 1 + 1 = 0.



In wireless technology, the word *interference* is typically used in a wider sense, for disturbance through other RF sources, e.g. neighbouring channels.

Destructive Interference

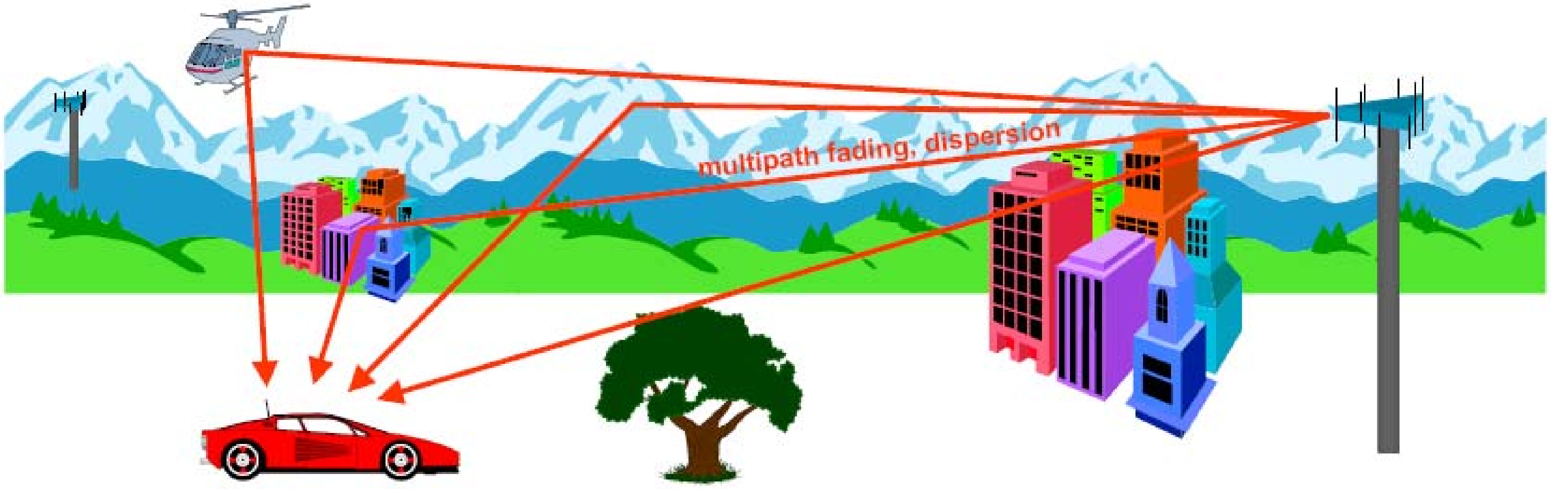


- Conditions for complete, destructive interference between path_1 and path_2 :

$A_1 = A_2$
- Equal signal strengths

$d_1 - d_2 = (k + .5)\lambda$
- Odd multiple of one half wavelength path difference

Channel Dispersion

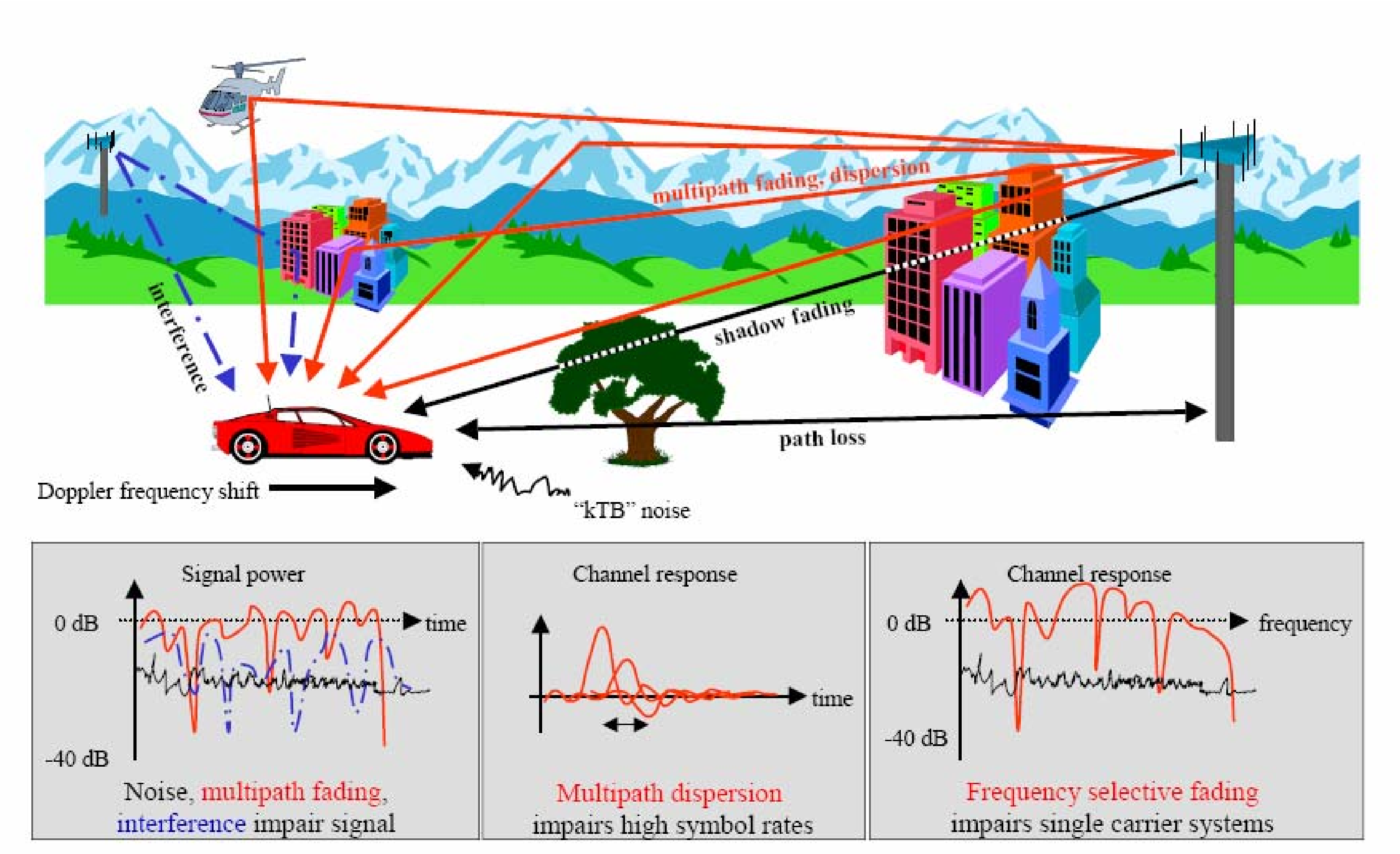


- Multipath reflections create time dispersion of the received signal
- Movement of the receiver, transmitter or objects in the environment create changes in the multipath environment

Atmospheric attenuation

- Starts becoming relevant above about 5 GHz
- Depends primarily, but not exclusively on water vapor content of the atmosphere
- Varies according to location, altitude, path elevation angle etc.
- Can add to system noise as well as attenuating desired signal
- Precipitation has a significant effect

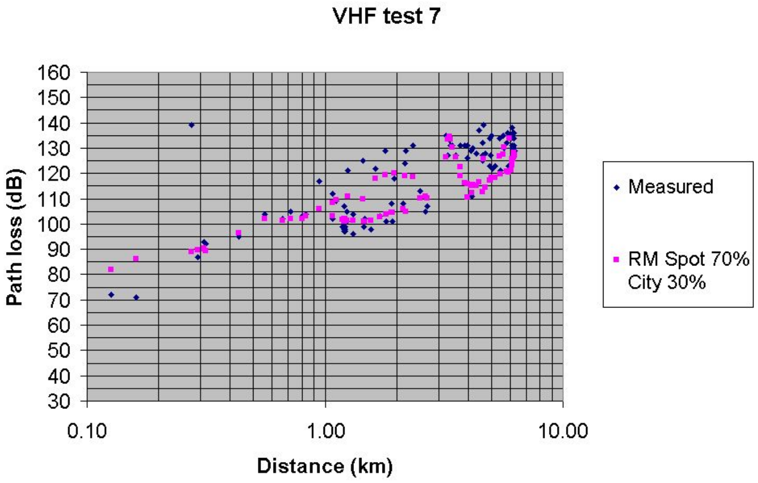
Put it all together -> Challenges!

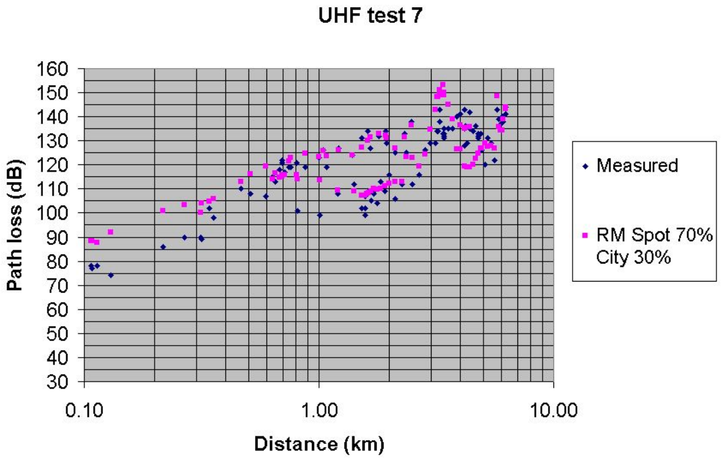


Irregular Terrain Model

- The ITS model of radio propagation for frequencies between 20 MHz and 20 GHz (the Longley-Rice model) is a general purpose model that can be applied to a large variety of engineering problems
- The model, which is based on electromagnetic theory and on statistical analyses of both terrain features and radio measurements, predicts the median attenuation of a radio signal as a function of distance and the variability of the signal in time and in space

How good is the model?



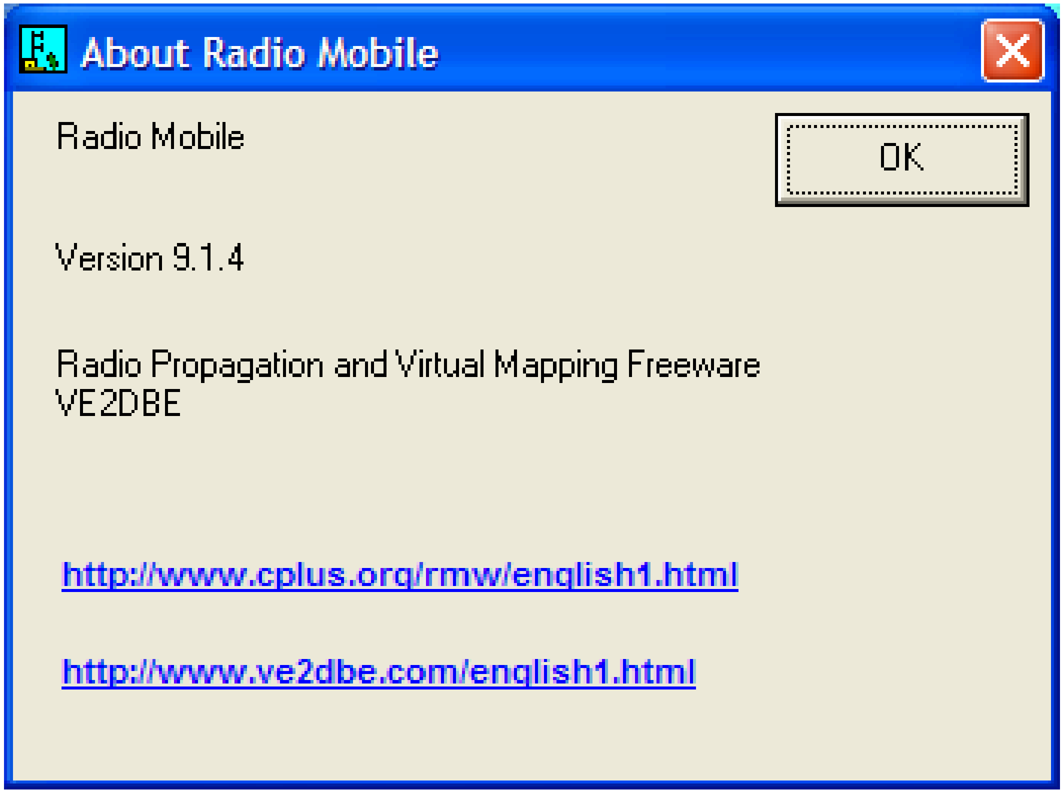


Step 1 → Installing Radio Mobile

- Visual Basic Runtime Service Pack 6 (Microsoft)
  - vbrun60sp6.exe
  - http://www.microsoft.com/downloads/details.aspx?familyid=7B9BA261-7A9C-43E7-9117-F673077FFB3C&displaylang=en
- Download Radio Mobile Program:
  - Option 1 → Radio Mobile Setup.zip
    - http://www.g3tvu.co.uk/Radio_Mobile.htm
  - Option 2 → VE2DBE website
    - http://www.cplus.org/rmw/download/download.html
- Creates a directory on your computer to extract the Radio Mobile program files
  - C:\Program Files\Radio Mobile
- Follow the instructions off the Radio Mobile website

http://www.cplus.org/rmw/english1.html

Make sure you have latest & greatest



Radio Mobile

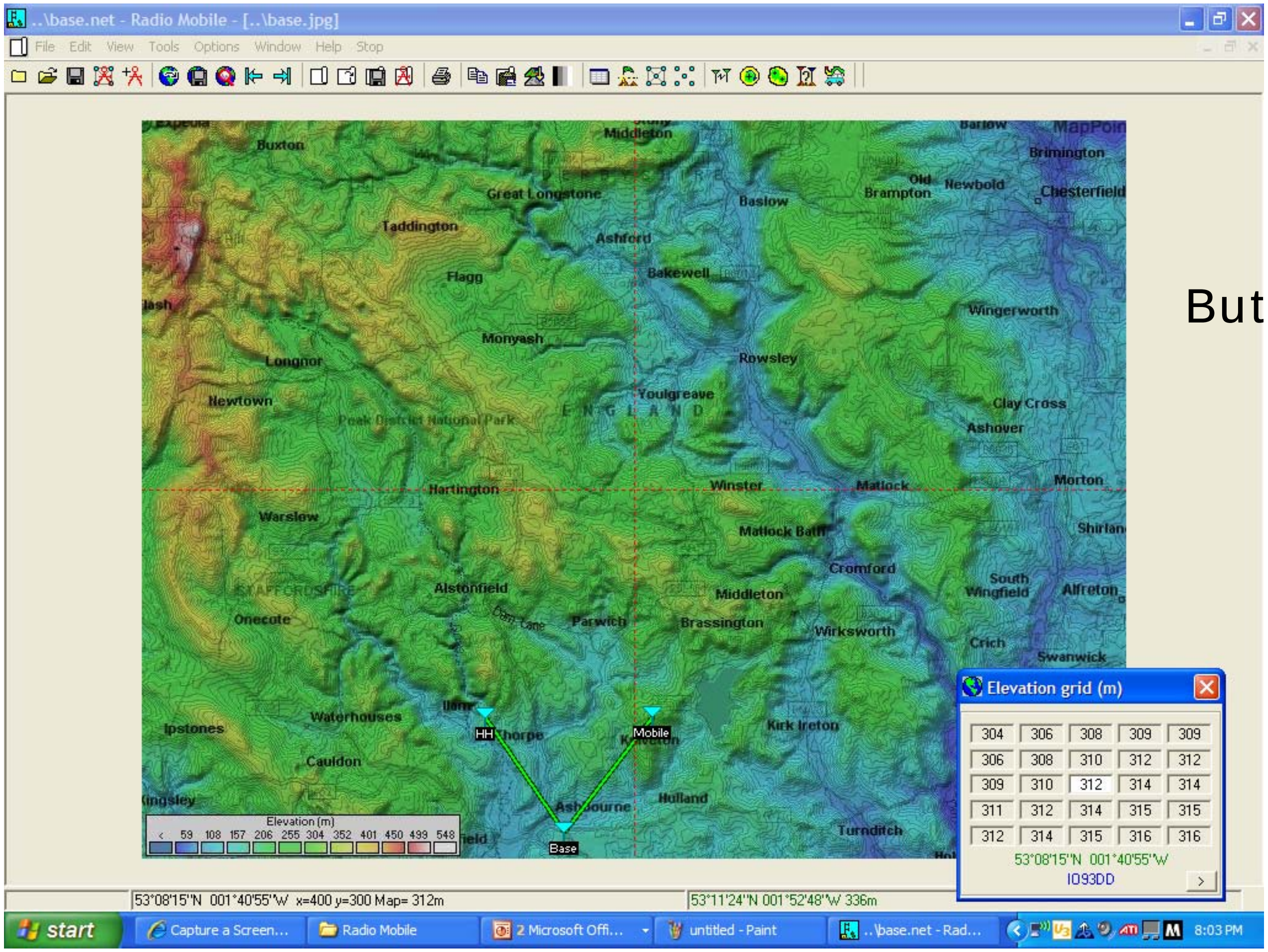
Version 9.1.4

Radio Propagation and Virtual Mapping Freeware
VE2DBE

http://www.cplus.org/rmw/english1.html

http://www.ve2dbe.com/english1.html

Open the Program



Elevation grid (m)

304	306	308	309	309
306	308	310	312	312
309	310	312	314	314
311	312	314	315	315
312	314	315	316	316

53°08'15"N 001°40'55"W
IO93DD

53°08'15"N 001°40'55"W x=400 y=300 Map= 312m

53°11'24"N 001°52'48"W 336m

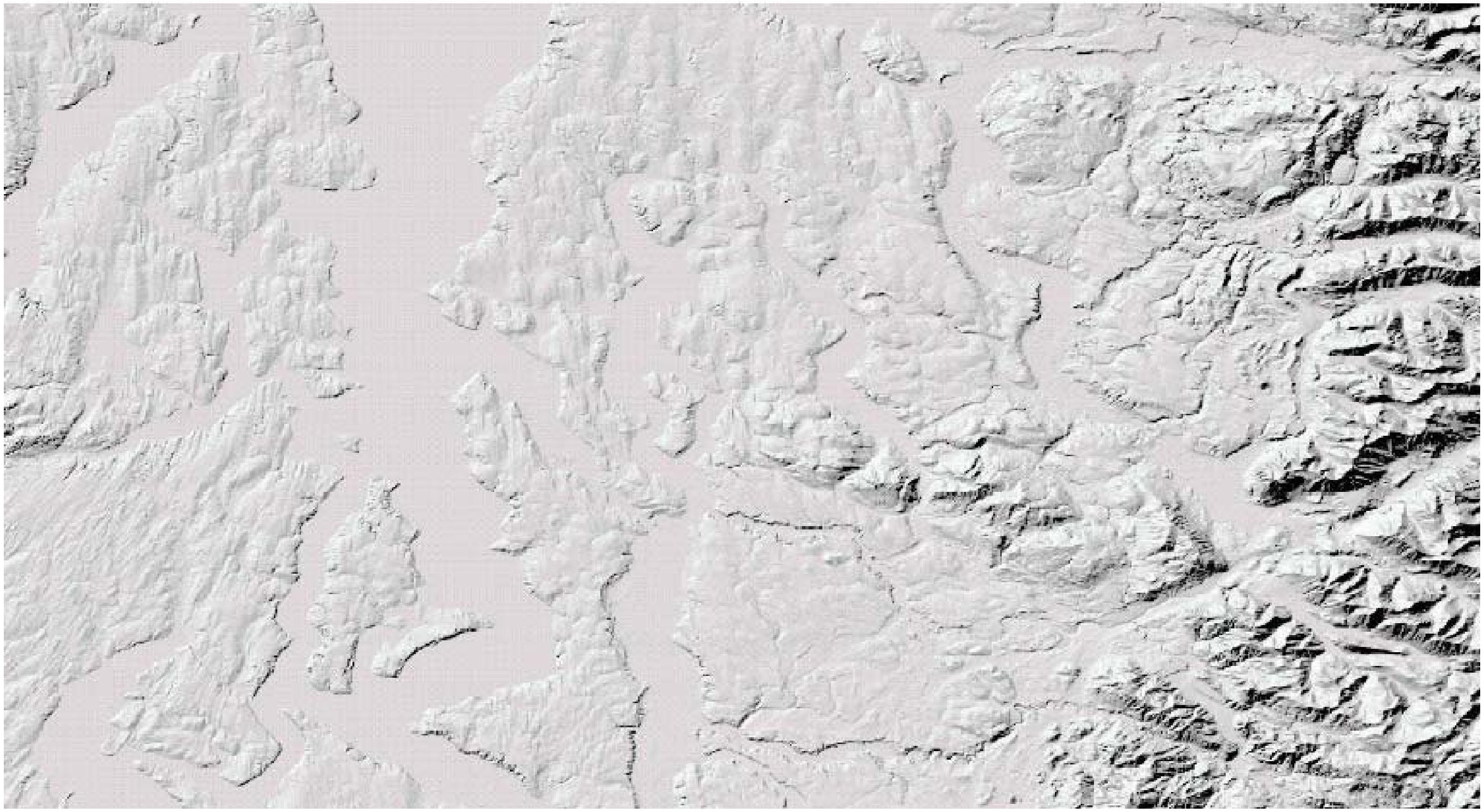
But I'm Not in the UK!!!

Obtaining Elevation Data

- Radio Mobile accepts several forms of elevation data
  - SRTM
    - Shuttle Radar Topology Mission data
    - For U.S., pre-defined areas of 1 arc second (30 meters)
    - Radio Mobile will automatically download the proper SRTM data when creating maps if connected to the Internet
  - GTOPO30
    - global digital elevation model (DEM) with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer)
    - http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html

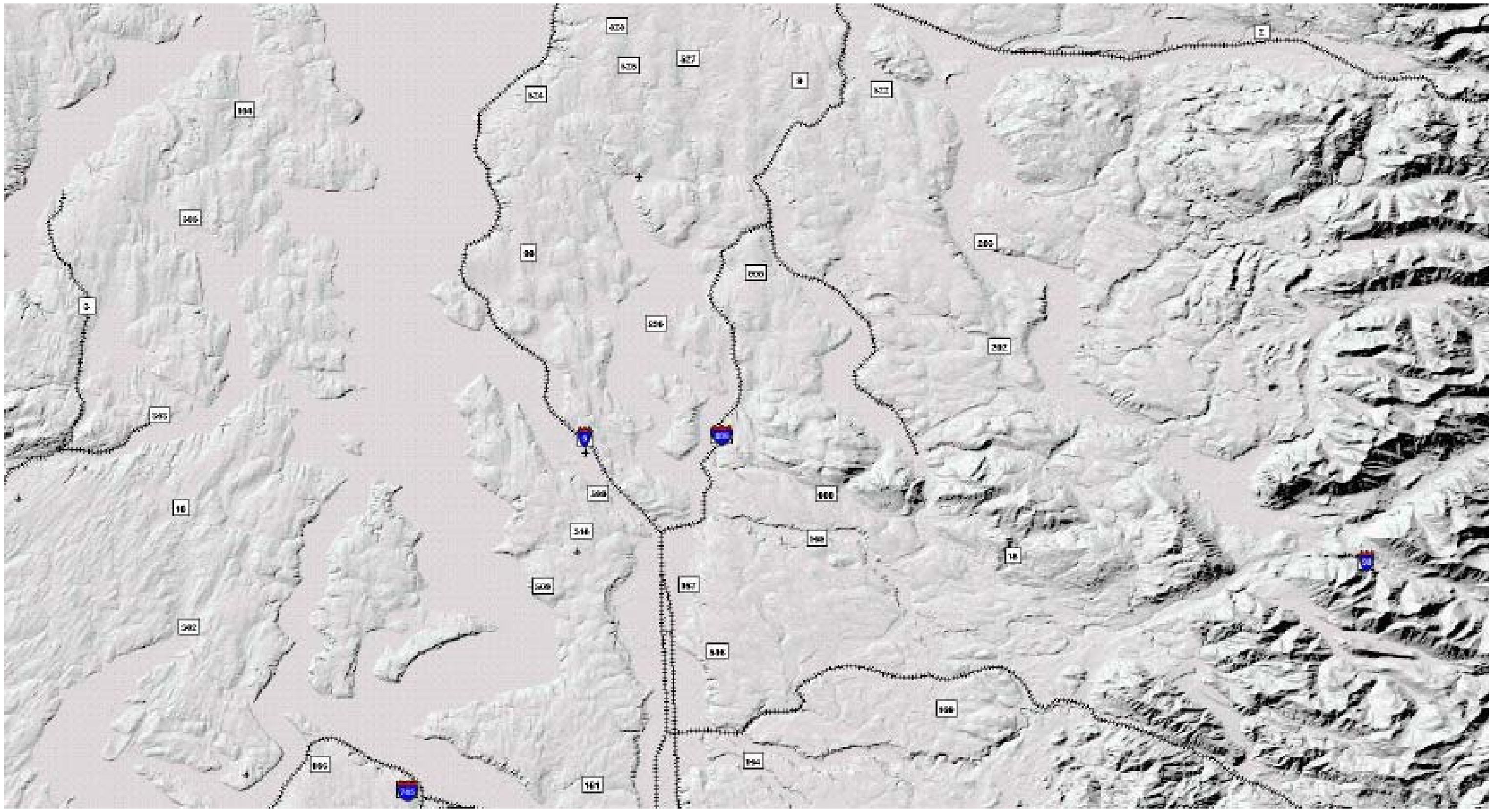
SRTM

Where is this???



SRTM

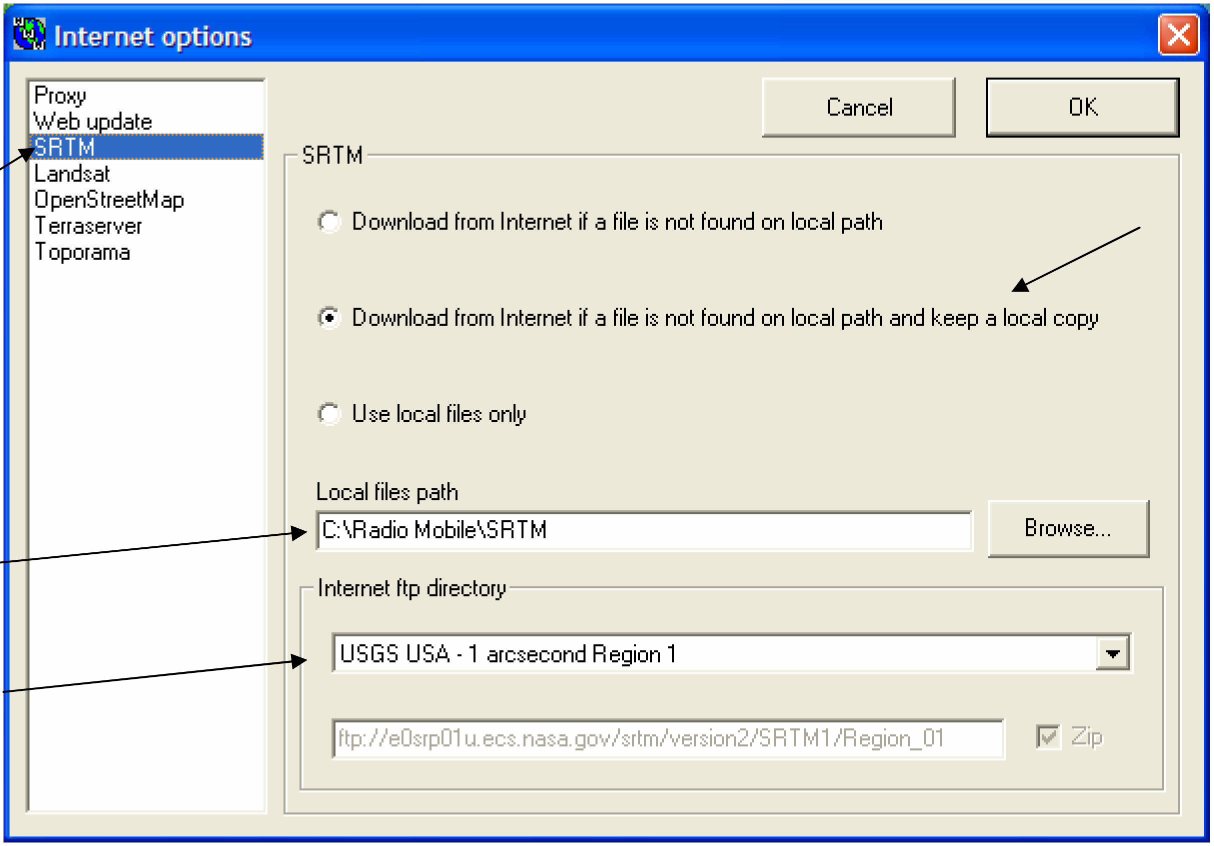
Does this help??



Set up Internet Options

- Options | Internet
  - Download from Internet if a file is not found and keep a local copy
- Internet FTP Directory
  - USGS USA-1 arcsecond Region 1 for Pacific Northwest
- http://www2.jpl.nasa.gov/srtm/
- http://srtm.usgs.gov/

Internet Options



SRTM

○ Download from Internet if a file is not found on local path

● Download from Internet if a file is not found on local path and keep a local copy

○ Use local files only

Local files path: C:\Radio Mobile\SRTM

Internet ftp directory: USGS USA - 1 arcsecond Region 1

ftp://e0srp01u.ecs.nasa.gov/srtm/version2/SRTM1/Region_01 ☑ Zip

Shuttle Radar Topography Mission Data

Store it here

Where to look

Set Map Properties to Your Area

Set size

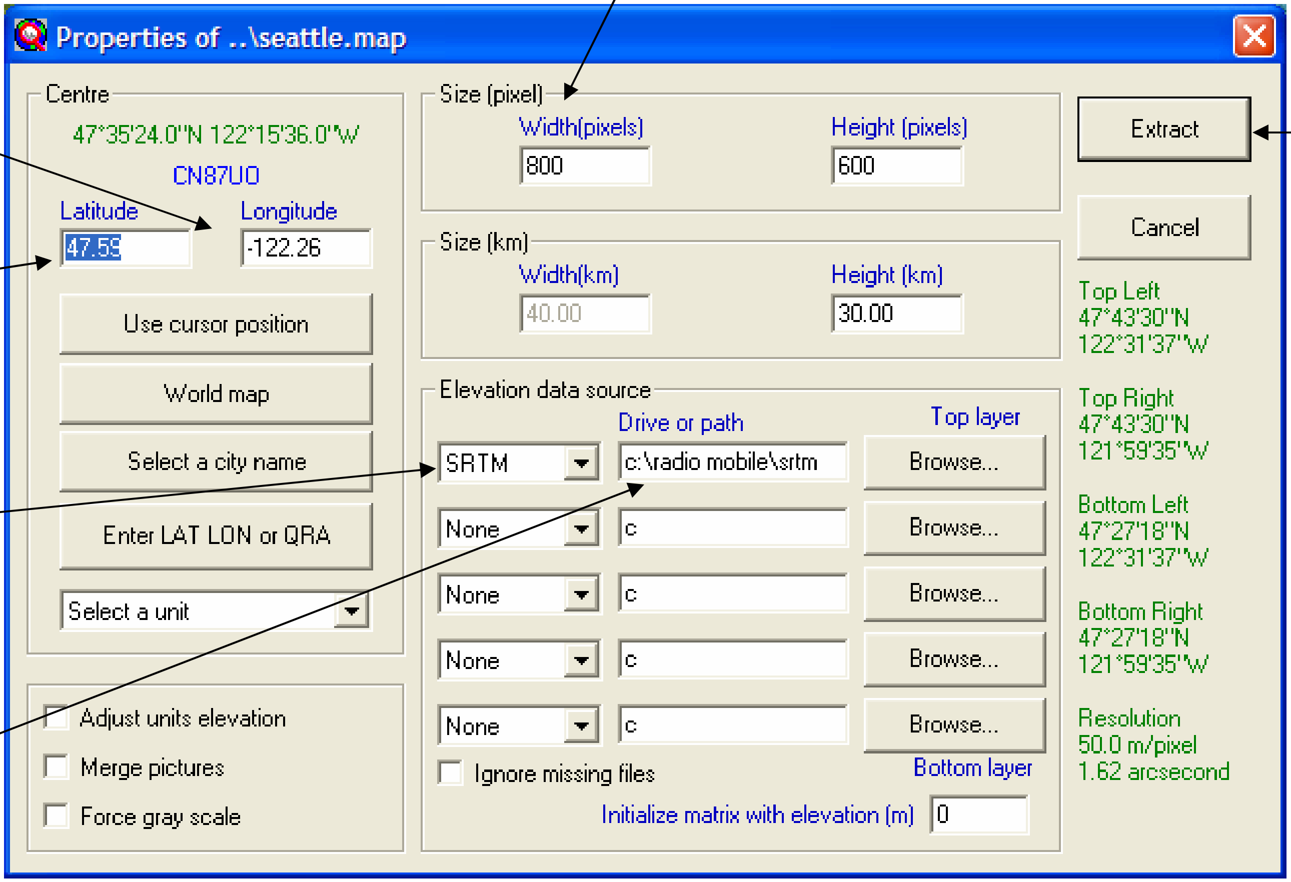
LON

LAT

GO!

Use SRTM

Store on your drive



Properties of ..\seattle.map

Centre
47°35'24.0"N 122°15'36.0"W
CN87UO
Latitude: 47.59
Longitude: -122.26

Size (pixel)
Width(pixels): 800
Height (pixels): 600

Size (km)
Width(km): 40.00
Height (km): 30.00

Elevation data source

	Drive or path	
SRTM	c:\radio mobile\srtm	Top layer
None	c	
None	c	
None	c	
None	c	Bottom layer

☐ Ignore missing files
Initialize matrix with elevation (m): 0

☐ Adjust units elevation
☐ Merge pictures
☐ Force gray scale

Top Left
47°43'30"N
122°31'37"W

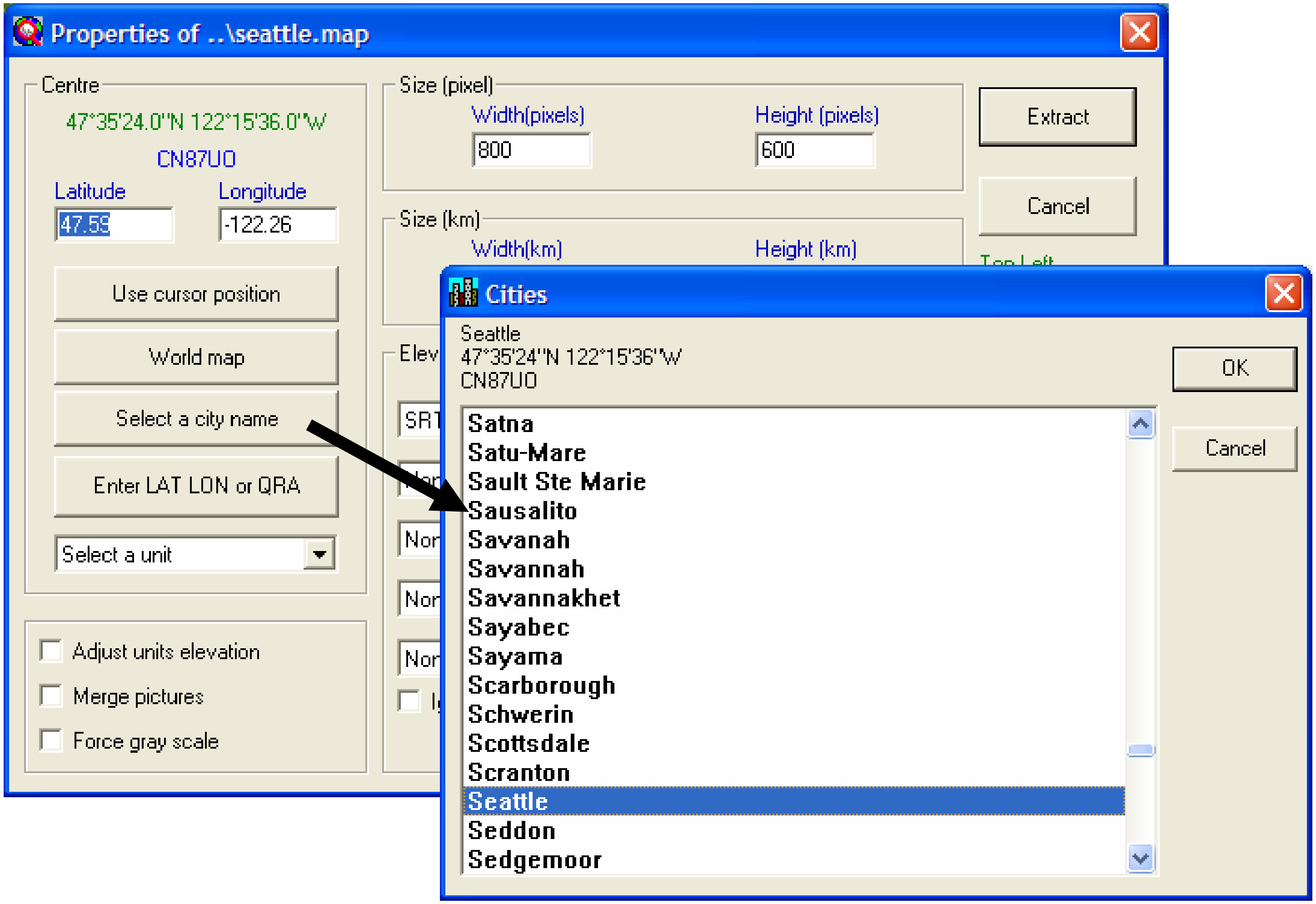
Top Right
47°43'30"N
121°59'35"W

Bottom Left
47°27'18"N
122°31'37"W

Bottom Right
47°27'18"N
121°59'35"W

Resolution
50.0 m/pixel
1.62 arcsecond

Alternatively → Select by City Name



Properties of ..\seattle.map

Centre
47°35'24.0"N 122°15'36.0"W
CN87UO

Latitude: 47.59
Longitude: -122.26

☐ Adjust units elevation
☐ Merge pictures
☐ Force gray scale

Size (pixel)
Width(pixels): 800
Height (pixels): 600

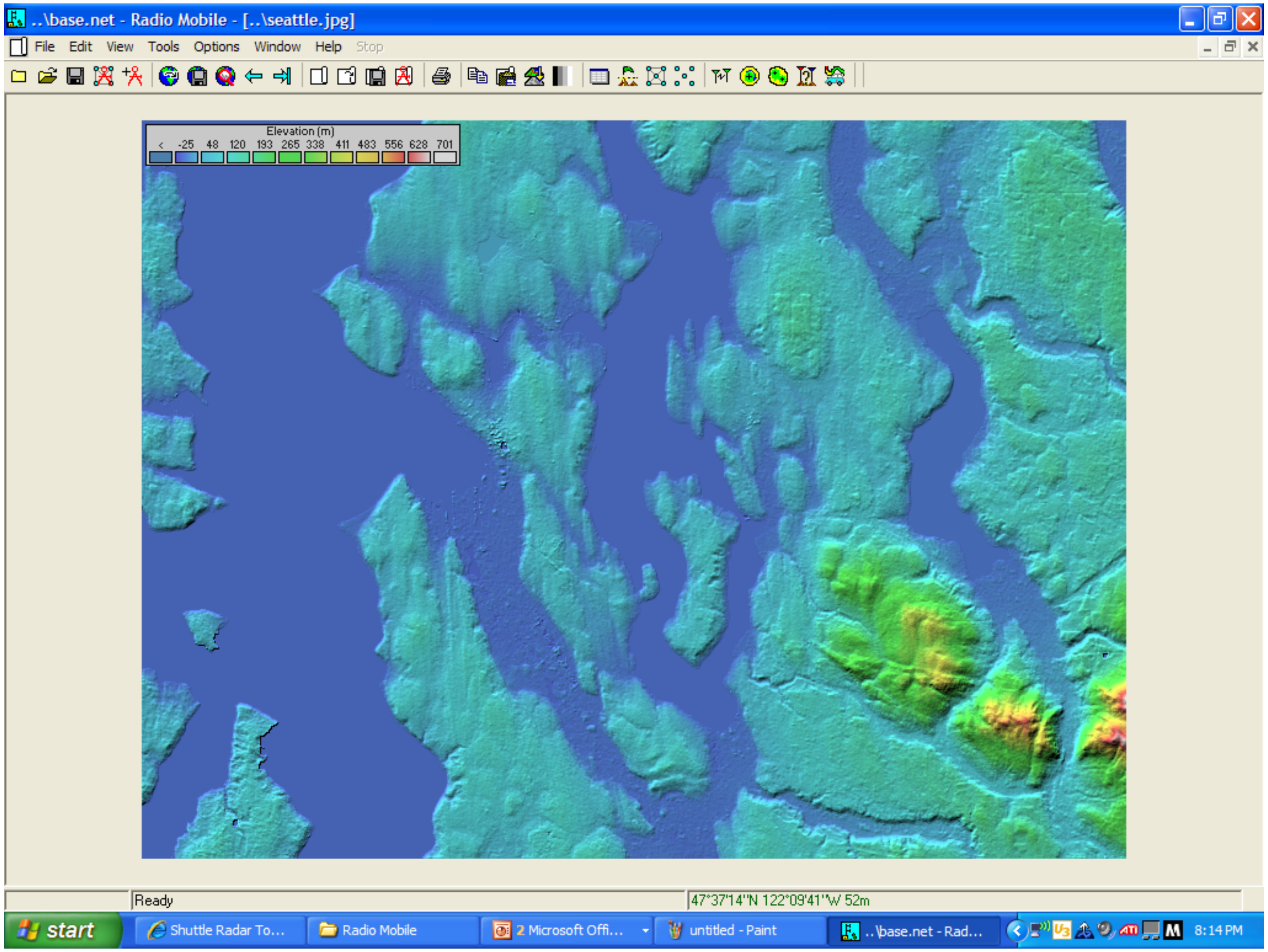
Size (km)
Width(km)
Height (km)

Cities

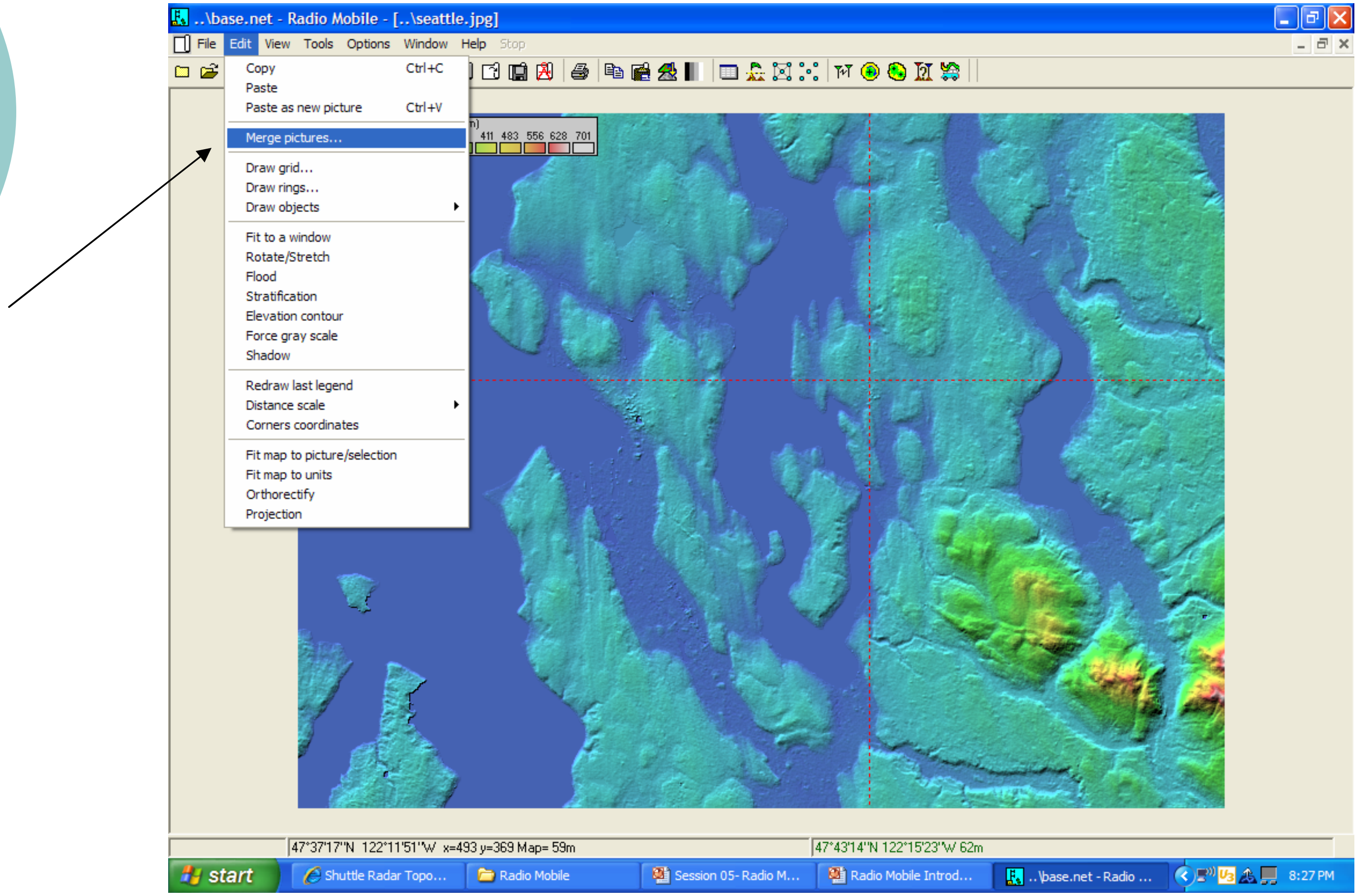
Seattle
47°35'24"N 122°15'36"W
CN87UO

Satna
Satu-Mare
Sault Ste Marie
Sausalito
Savanah
Savannah
Savannakhet
Sayabec
Sayama
Scarborough
Schwerin
Scottsdale
Scranton
Seattle
Seddon
Sedgemoor

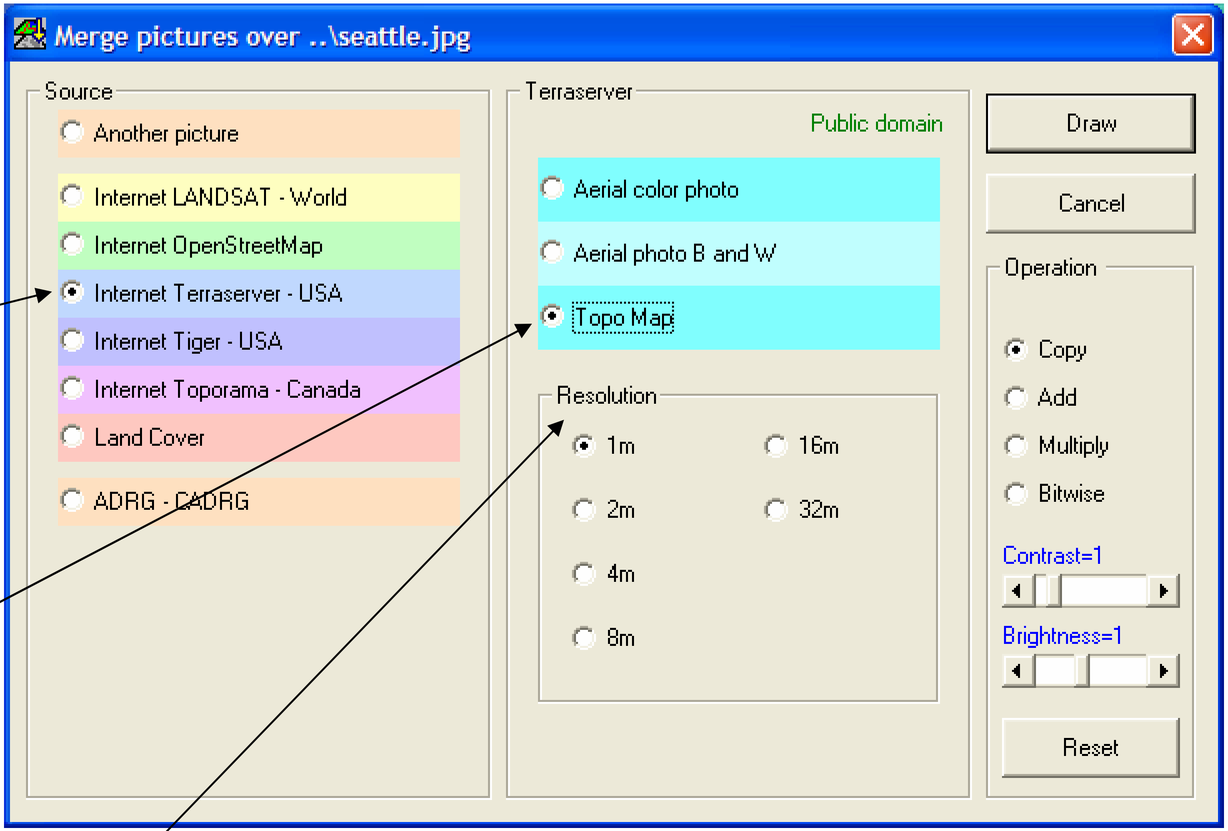
Result → Seattle Map



Merging Pictures



Merge Pictures



Merge pictures over ..\seattle.jpg

Source
- ○ Another picture
- ○ Internet LANDSAT - World
- ○ Internet OpenStreetMap
- ● Internet Terraserver - USA
- ○ Internet Tiger - USA
- ○ Internet Toporama - Canada
- ○ Land Cover
- ○ ADRG - CADRG

Terraserver

Public domain
- ○ Aerial color photo
- ○ Aerial photo B and W
- ● Topo Map

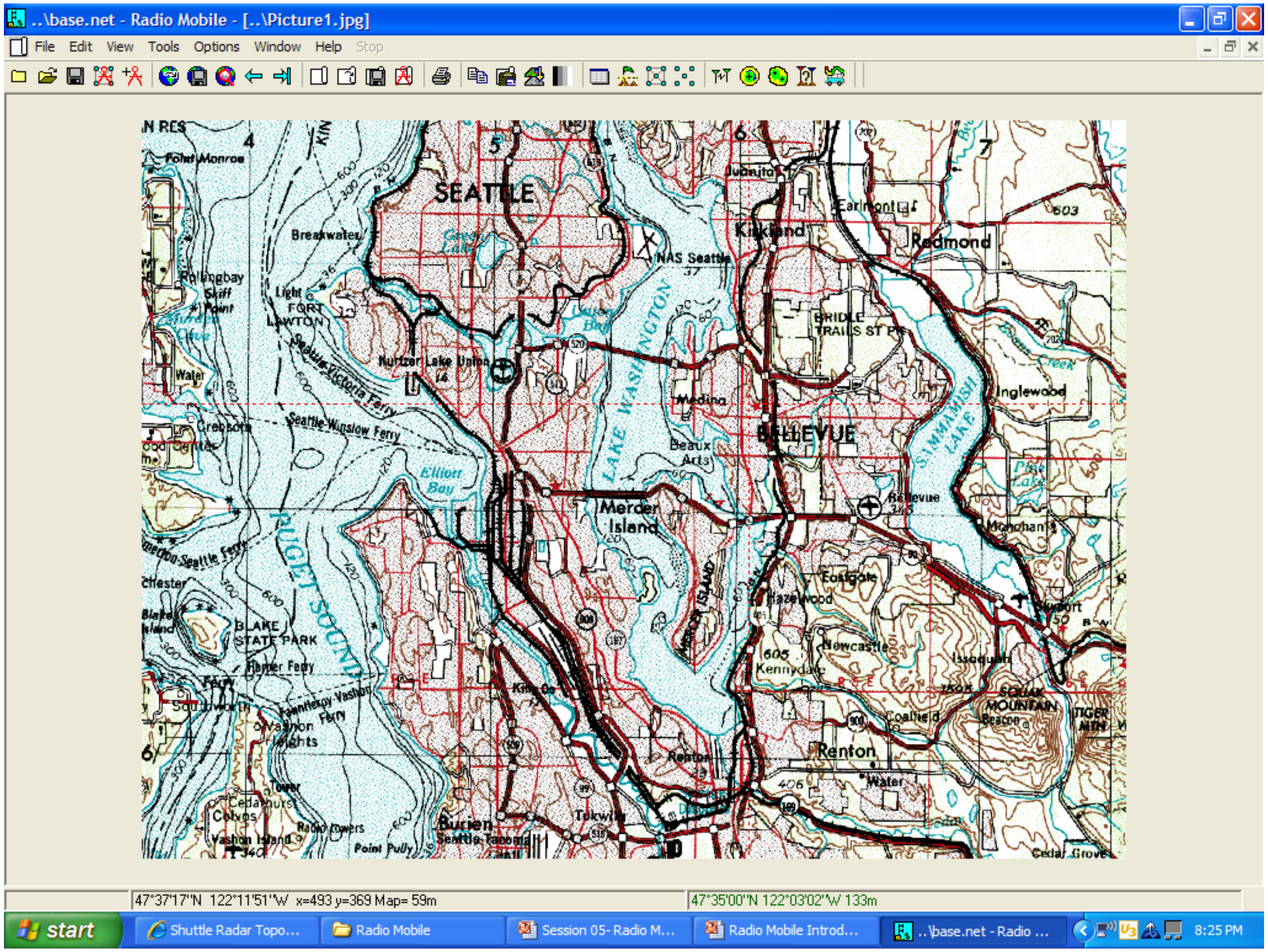
Resolution
- ● 1m
- ○ 16m
- ○ 2m
- ○ 32m
- ○ 4m
- ○ 8m

Operation
- ● Copy
- ○ Add
- ○ Multiply
- ○ Bitwise

Contrast=1

Brightness=1

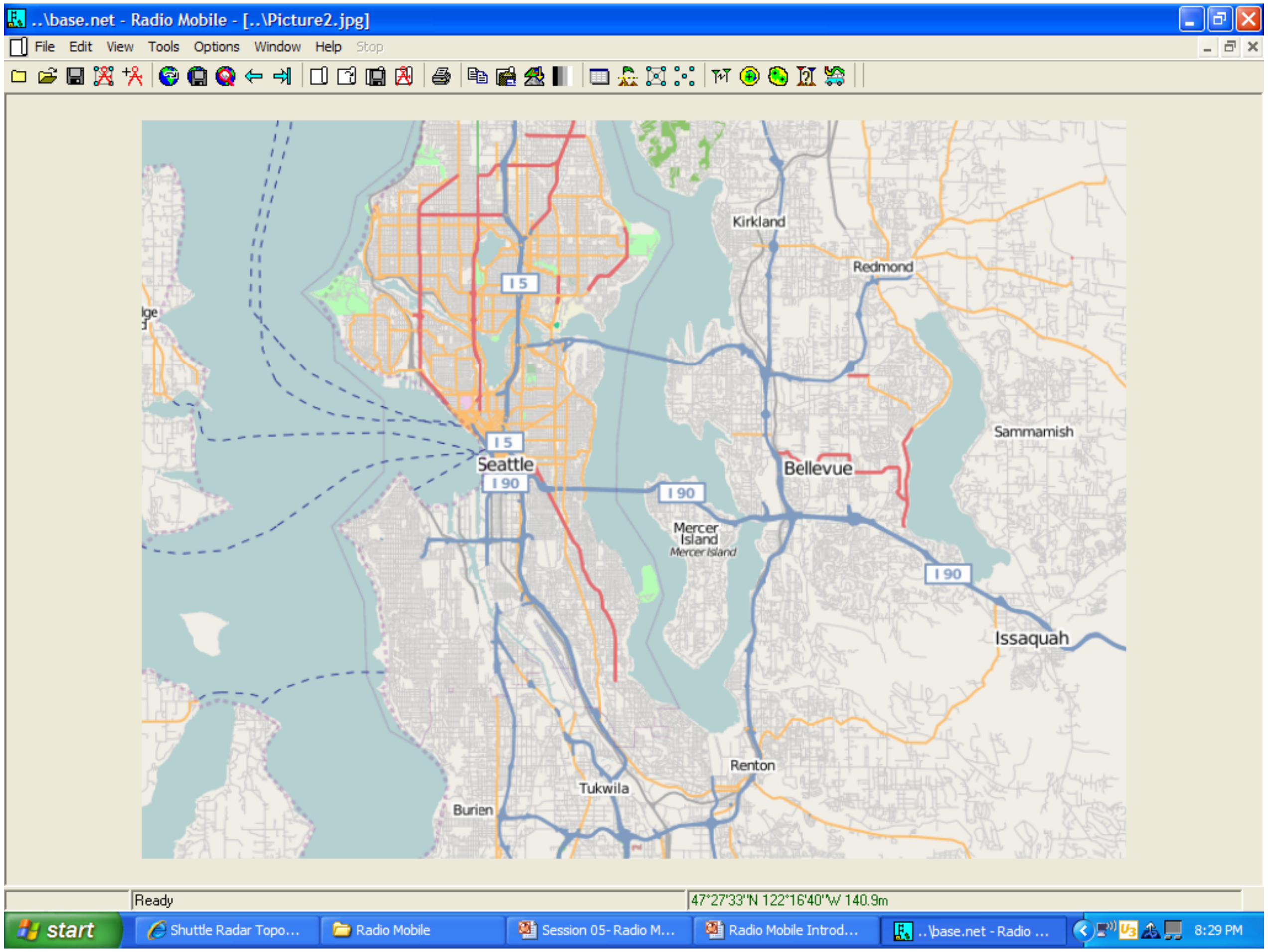
Seattle with Topo 32m Resolution



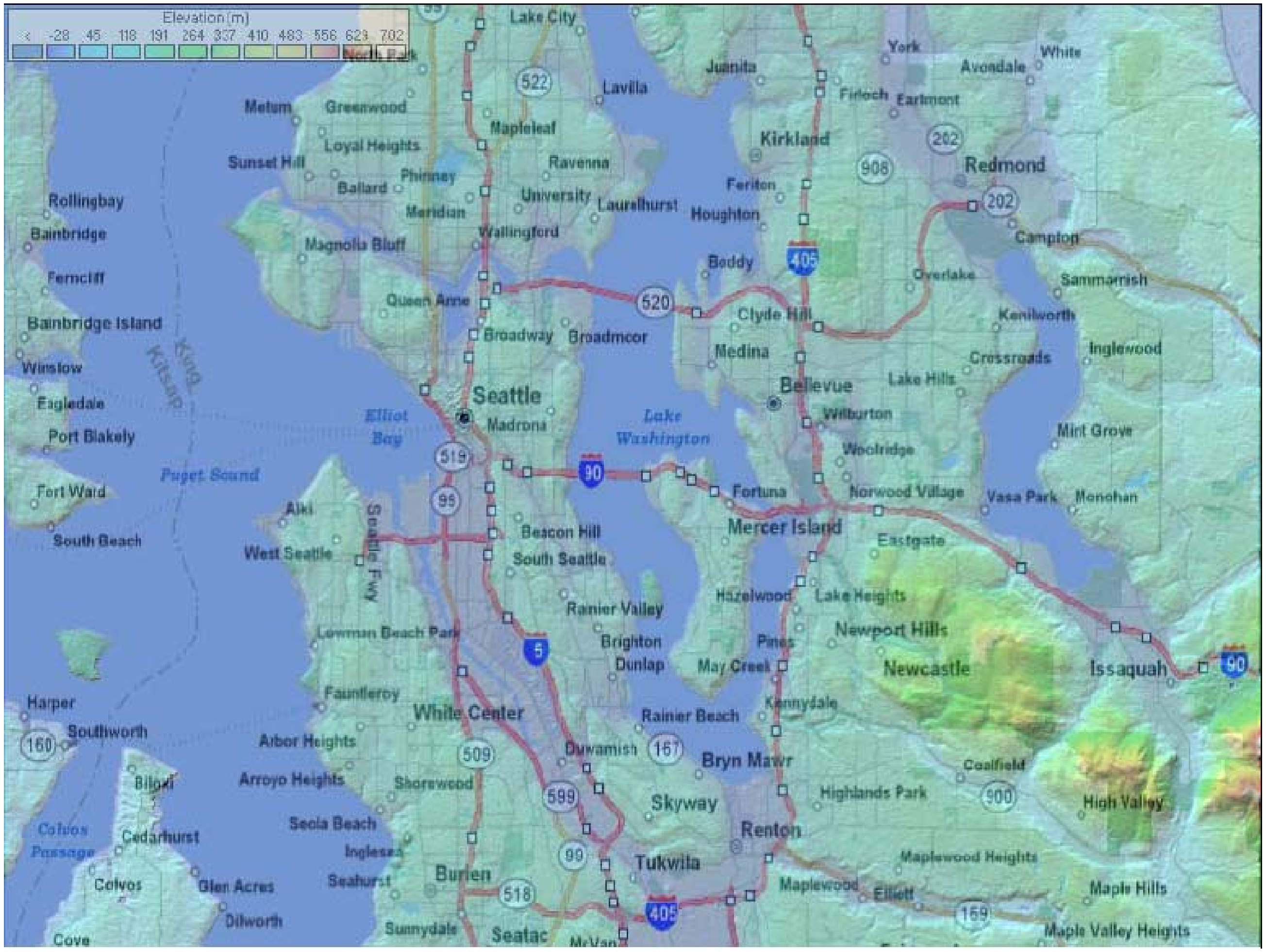
47°37'17"N 122°11'51"W x=493 y=369 Map= 59m

47°35'00"N 122°03'02"W 133m

Seattle with Open Street Map



Seattle Map with MapQuest



Units, Systems & Networks

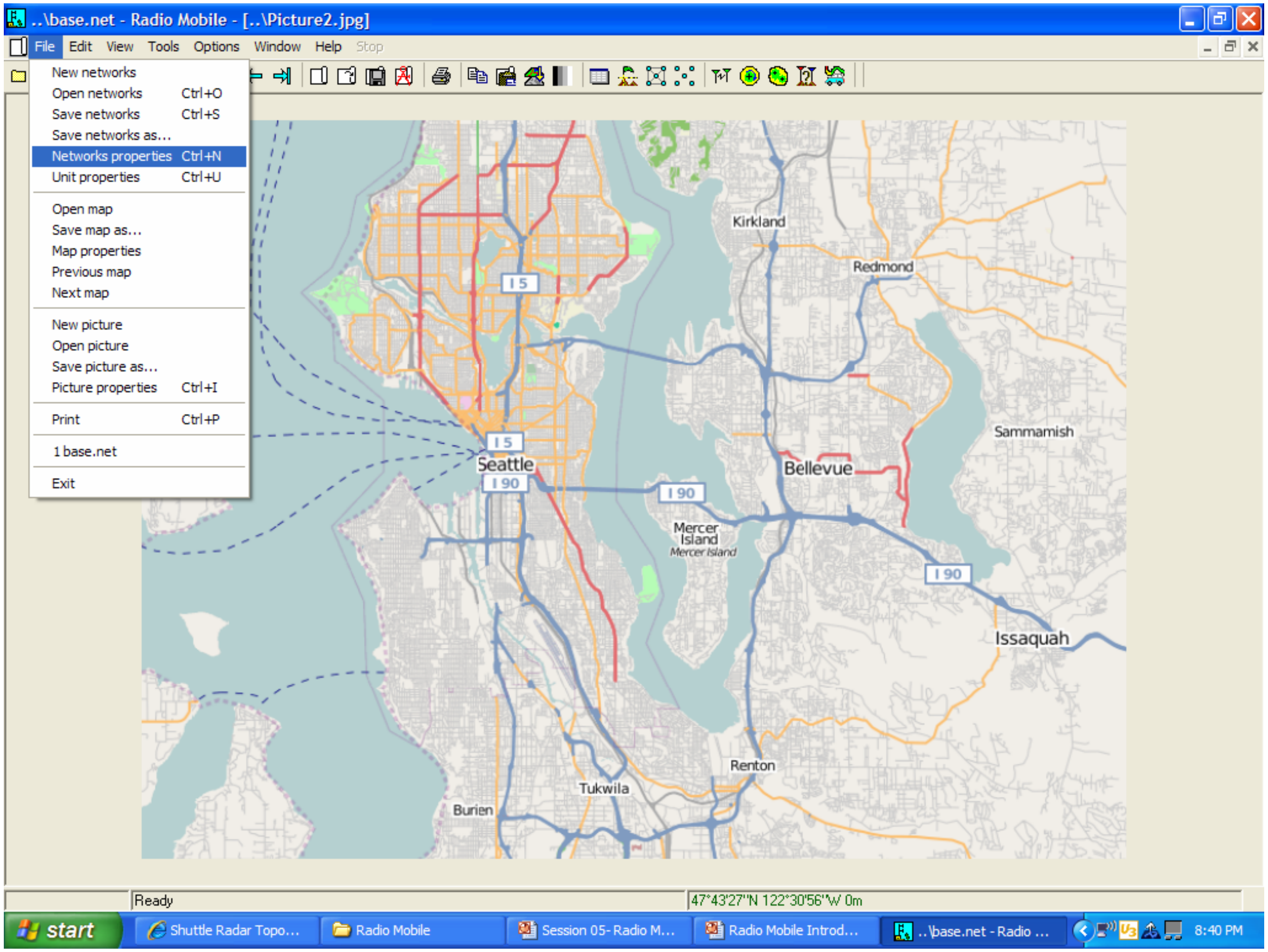
- ***UNIT***
  - ***an actual radio station which can be placed on the map, its radio performance specification is given by its SYSTEM***
- ***SYSTEM***
  - ***a set of specific parameters defining the performance of any type of radio station***
- ***NETWORK***
  - ***a specified group of stations which are required to intercommunicate***

Systems and Networks

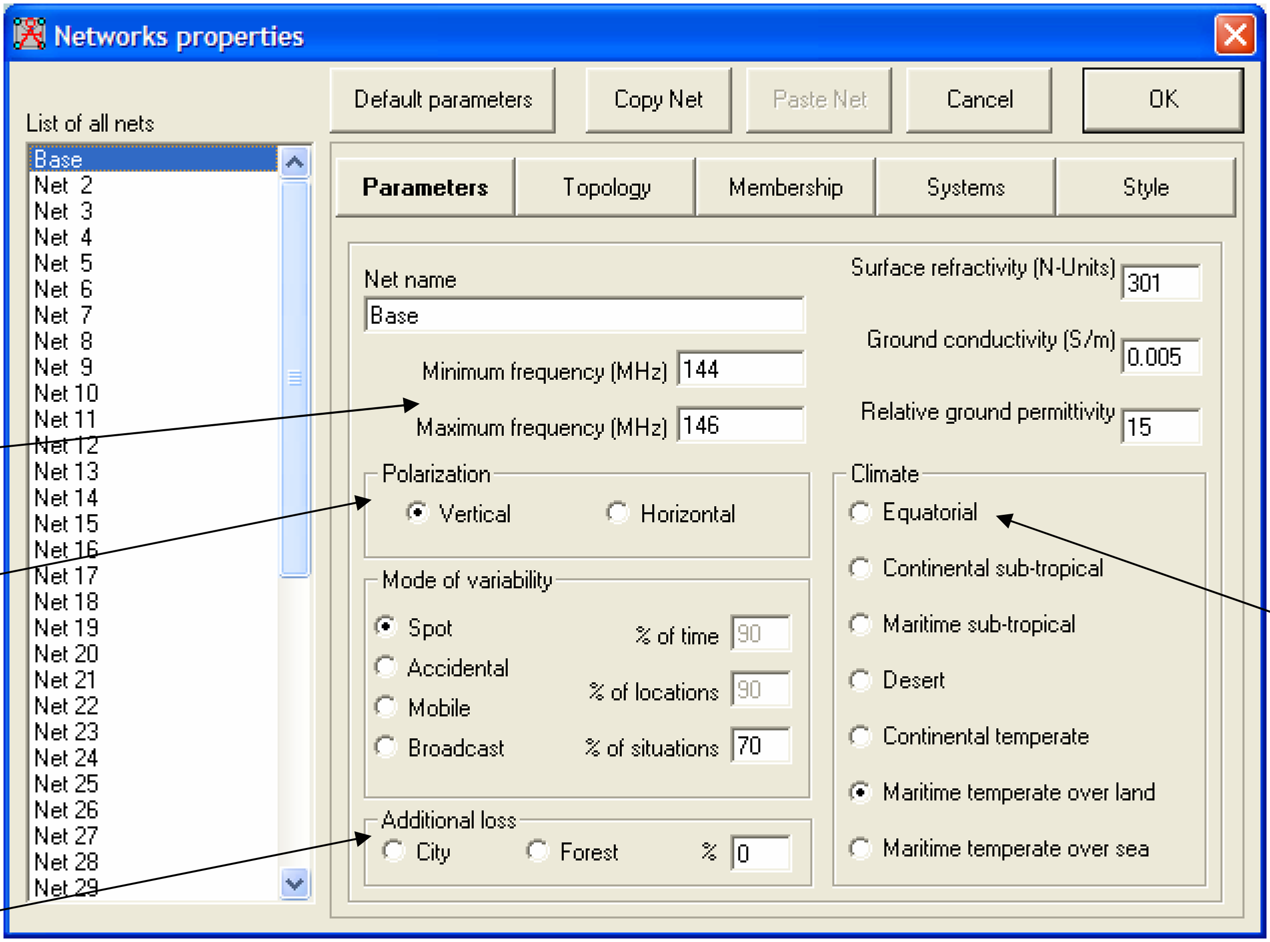
- Before you can use Radio Mobile to plot RF performance you need to set up networks and the systems within those networks

- Click on the File menu and select "Networks Properties"

Networks Properties



Networks Properties



Net name: Base

Minimum frequency (MHz): 144

Maximum frequency (MHz): 146

Surface refractivity (N-Units): 301

Ground conductivity (S/m): 0.005

Relative ground permittivity: 15

Polarization

● Vertical ○ Horizontal

Mode of variability

● Spot

○ Accidental

○ Mobile

○ Broadcast

% of time: 90

% of locations: 90

% of situations: 70

Additional loss

○ City ○ Forest %: 0

Climate

○ Equatorial

○ Continental sub-tropical

○ Maritime sub-tropical

○ Desert

○ Continental temperate

● Maritime temperate over land

○ Maritime temperate over sea

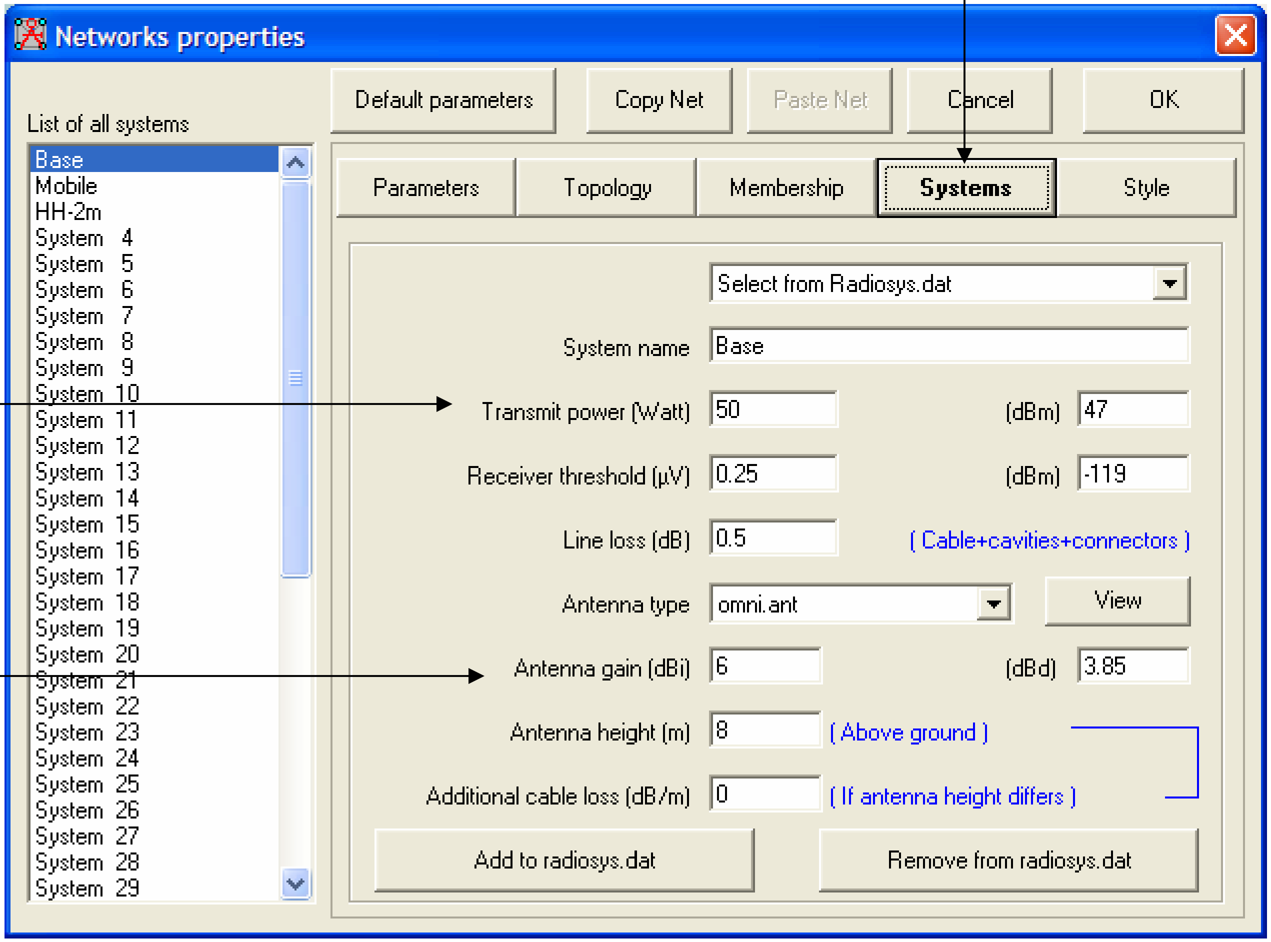
Frequency Band

Antenna Polarization

Climate

Loss

System Properties



List of all systems

- Base
- Mobile
- HH-2m
- System 4
- System 5
- System 6
- System 7
- System 8
- System 9
- System 10
- System 11
- System 12
- System 13
- System 14
- System 15
- System 16
- System 17
- System 18
- System 19
- System 20
- System 21
- System 22
- System 23
- System 24
- System 25
- System 26
- System 27
- System 28
- System 29

Select from Radiosys.dat

System name: Base

Transmit power (Watt): 50 (dBm): 47

Receiver threshold (µV): 0.25 (dBm): -119

Line loss (dB): 0.5 (Cable+cavities+connectors)

Antenna type: omni.ant

Antenna gain (dBi): 6 (dBd): 3.85

Antenna height (m): 8 (Above ground)

Additional cable loss (dB/m): 0 (If antenna height differs)

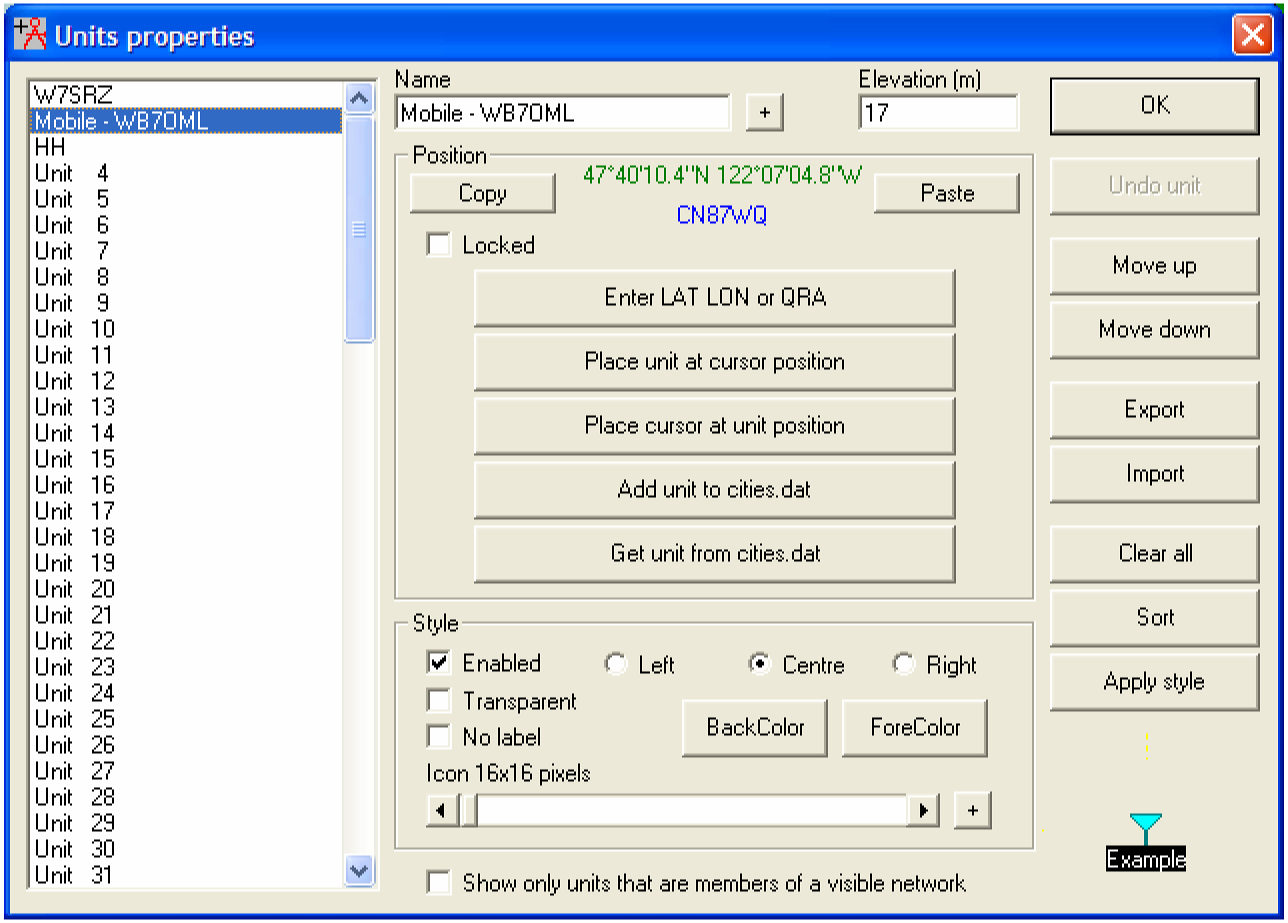
Tx Power

Antenna Parameters

Units Properties

- LAT/LON or place at cursor location
- Can add meaningful labels
- Network Properties -> Membership
  - Add units to the network
  - Specify Antenna Height for Units

Units Properties



Units properties

W7SRZ
Mobile - WB7OML
HH
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8
Unit 9
Unit 10
Unit 11
Unit 12
Unit 13
Unit 14
Unit 15
Unit 16
Unit 17
Unit 18
Unit 19
Unit 20
Unit 21
Unit 22
Unit 23
Unit 24
Unit 25
Unit 26
Unit 27
Unit 28
Unit 29
Unit 30
Unit 31

Name: Mobile - WB7OML

Elevation (m): 17

Position

47°40'10.4"N 122°07'04.8"W

CN87WQ

☐ Locked

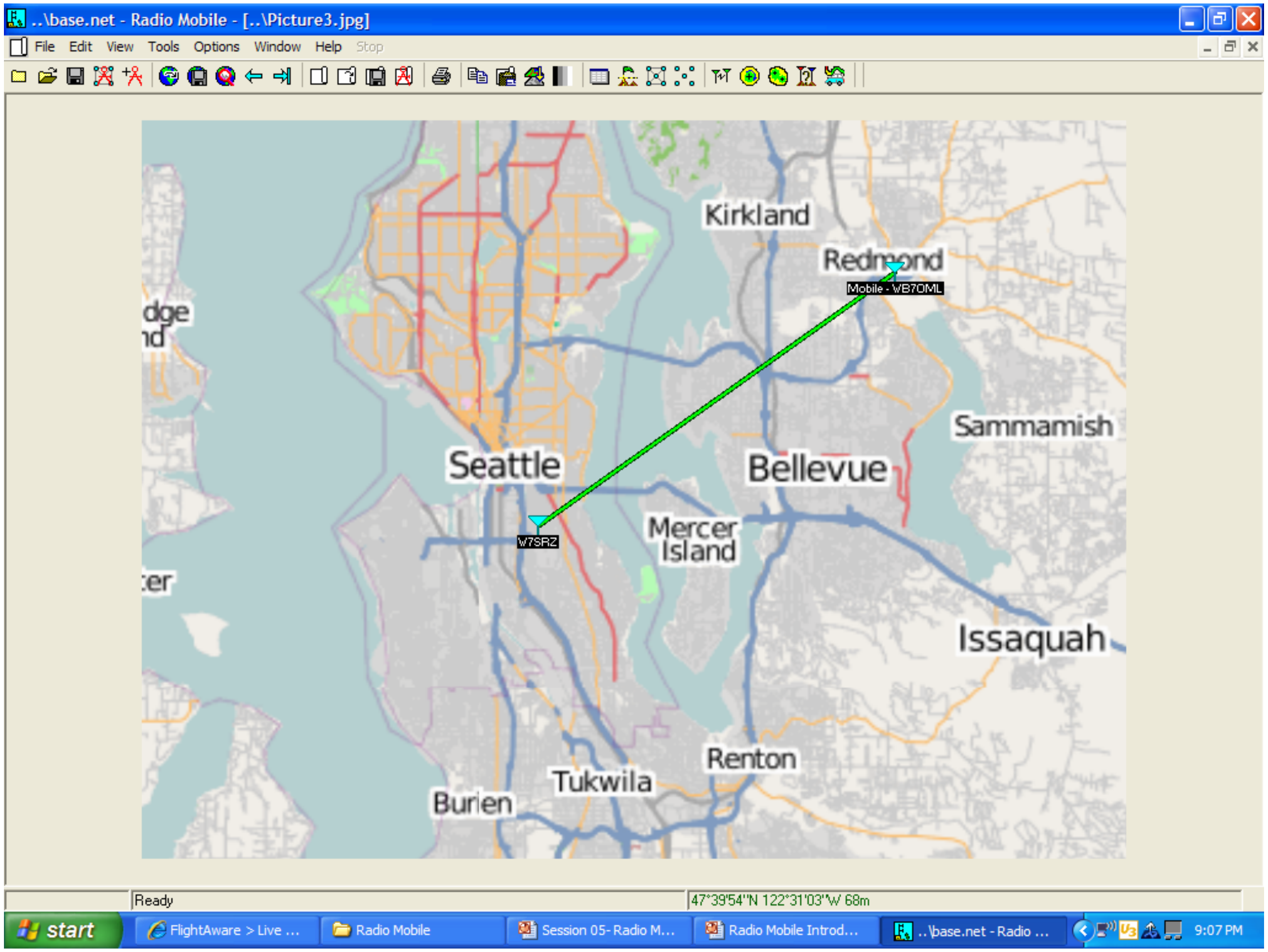
Style

☑ Enabled
○ Left ● Centre ○ Right
☐ Transparent
☐ No label

Icon 16x16 pixels

☐ Show only units that are members of a visible network

W7SRZ to WB7OML Example



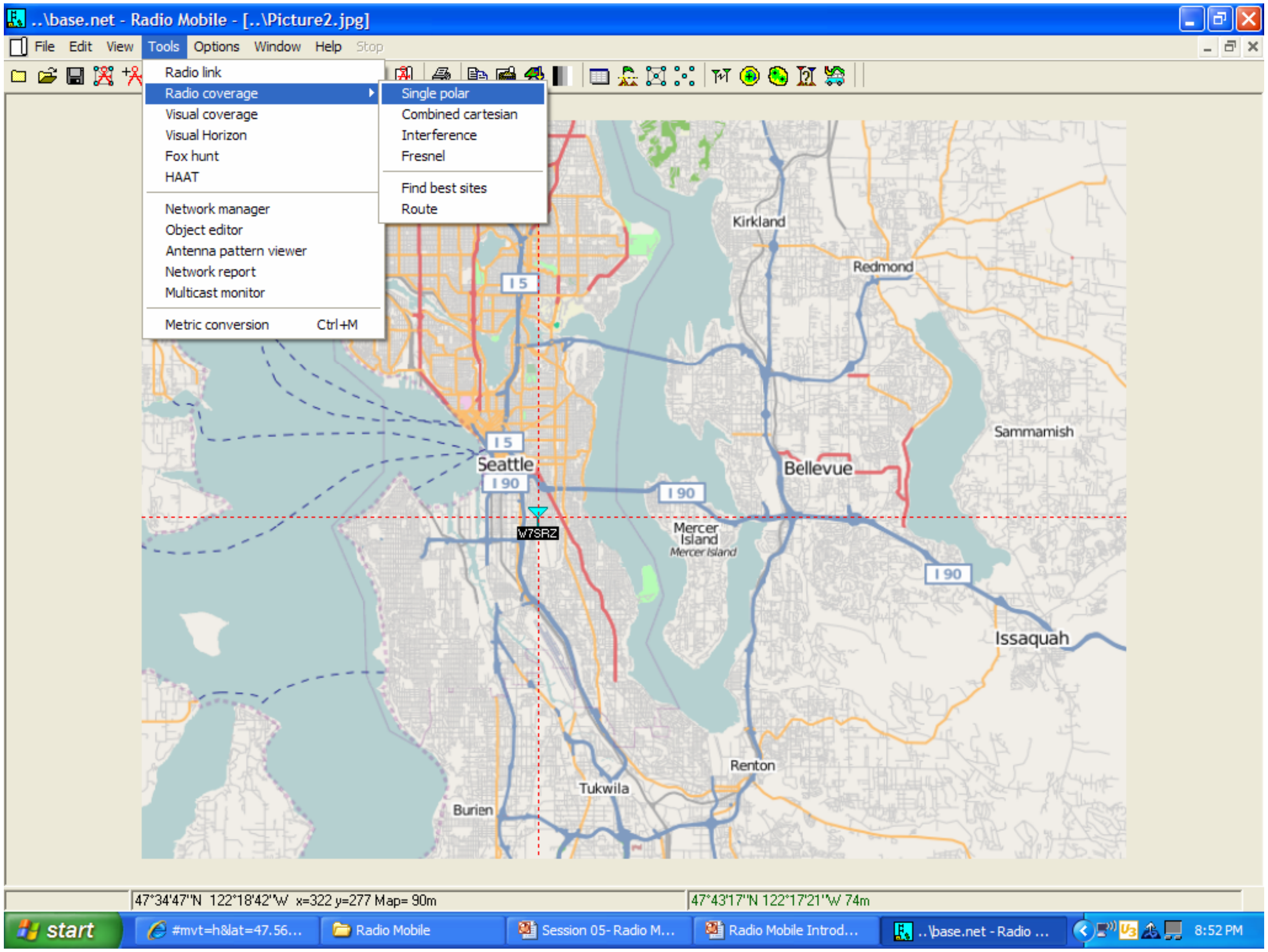
Ready

47°39'54"N 122°31'03"W 68m

RF Coverage Plot

- Click on View, select Radio Coverage and then Single Polar from the menu
- Make sure the center unit selected is W7SRZ
- Set the Mobile unit to Redmond Ridge
- The Network should be W7SRZ

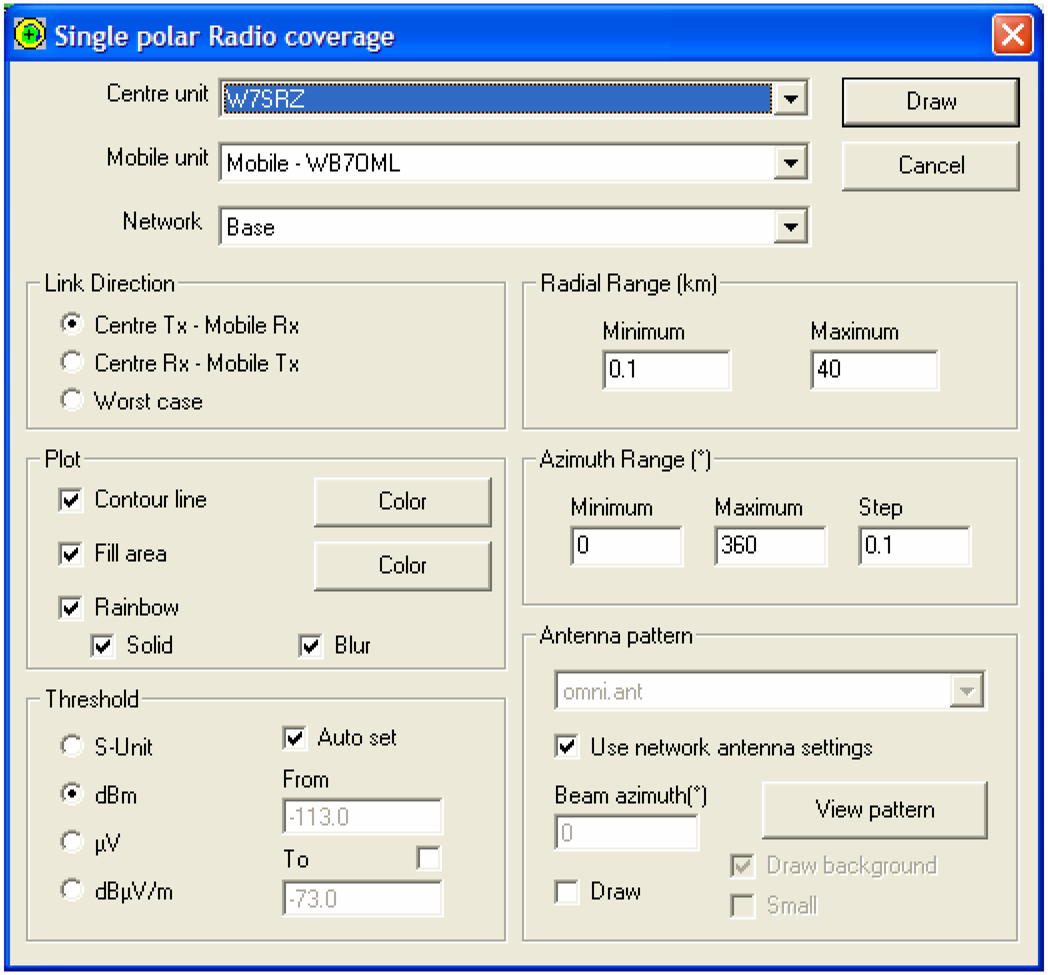
Radio Coverage



47°34'47"N 122°18'42"W x=322 y=277 Map= 90m

47°43'17"N 122°17'21"W 74m

Radio Coverage Parameters



Centre unit: W7SRZ

Mobile unit: Mobile - WB7OML

Network: Base

Link Direction
- ● Centre Tx - Mobile Rx
- ○ Centre Rx - Mobile Tx
- ○ Worst case

Radial Range (km)
- Minimum: 0.1
- Maximum: 40

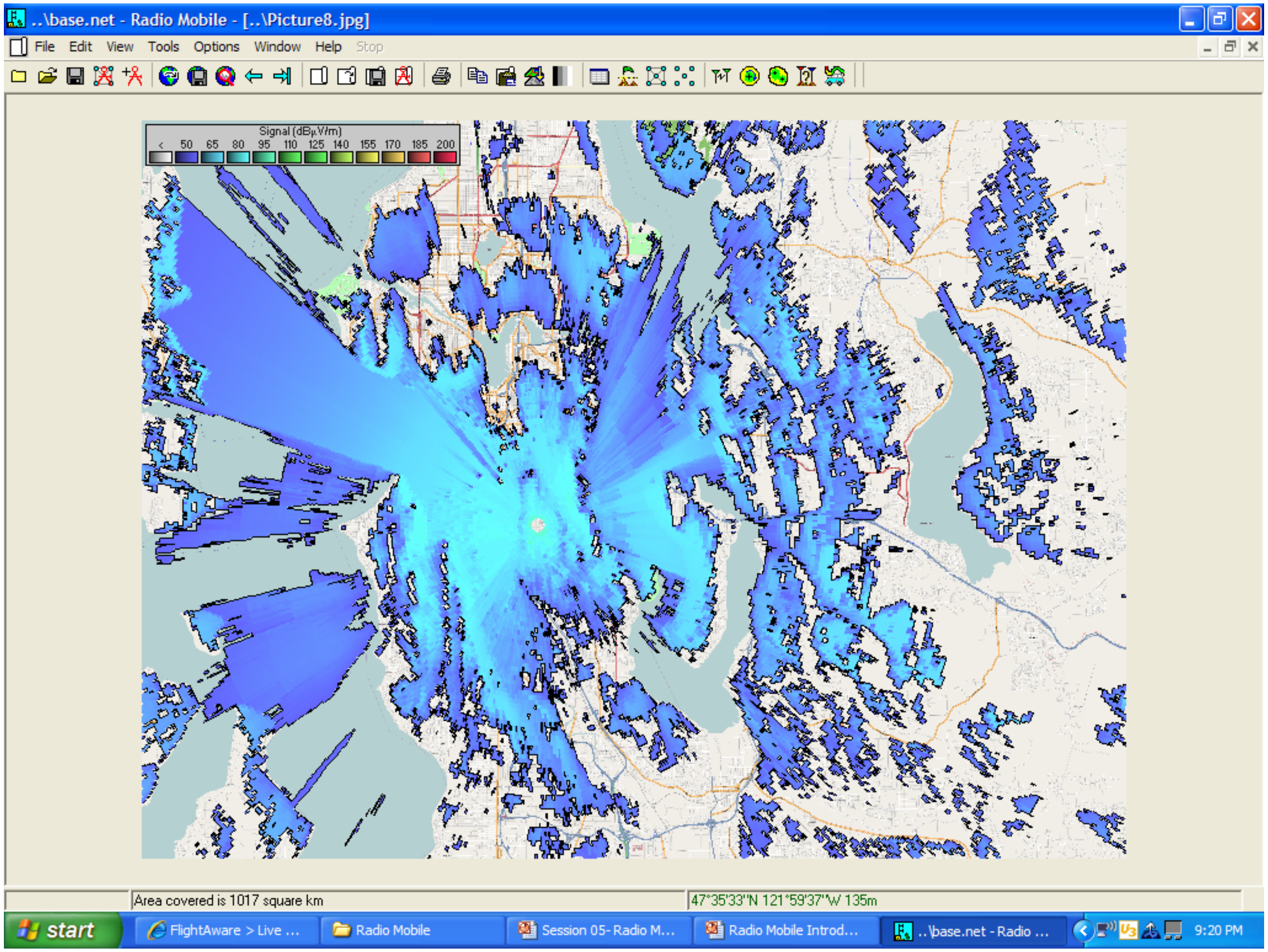
Plot
- ☑ Contour line
- ☑ Fill area
- ☑ Rainbow
  - ☑ Solid
  - ☑ Blur

Azimuth Range (°)
- Minimum: 0
- Maximum: 360
- Step: 0.1

Threshold
- ○ S-Unit
- ● dBm
- ○ µV
- ○ dBµV/m
- ☑ Auto set
- From: -113.0
- To ☐: -73.0

Antenna pattern
- omni.ant
- ☑ Use network antenna settings
- Beam azimuth(°): 0
- ☐ Draw
- ☑ Draw background
- ☐ Small

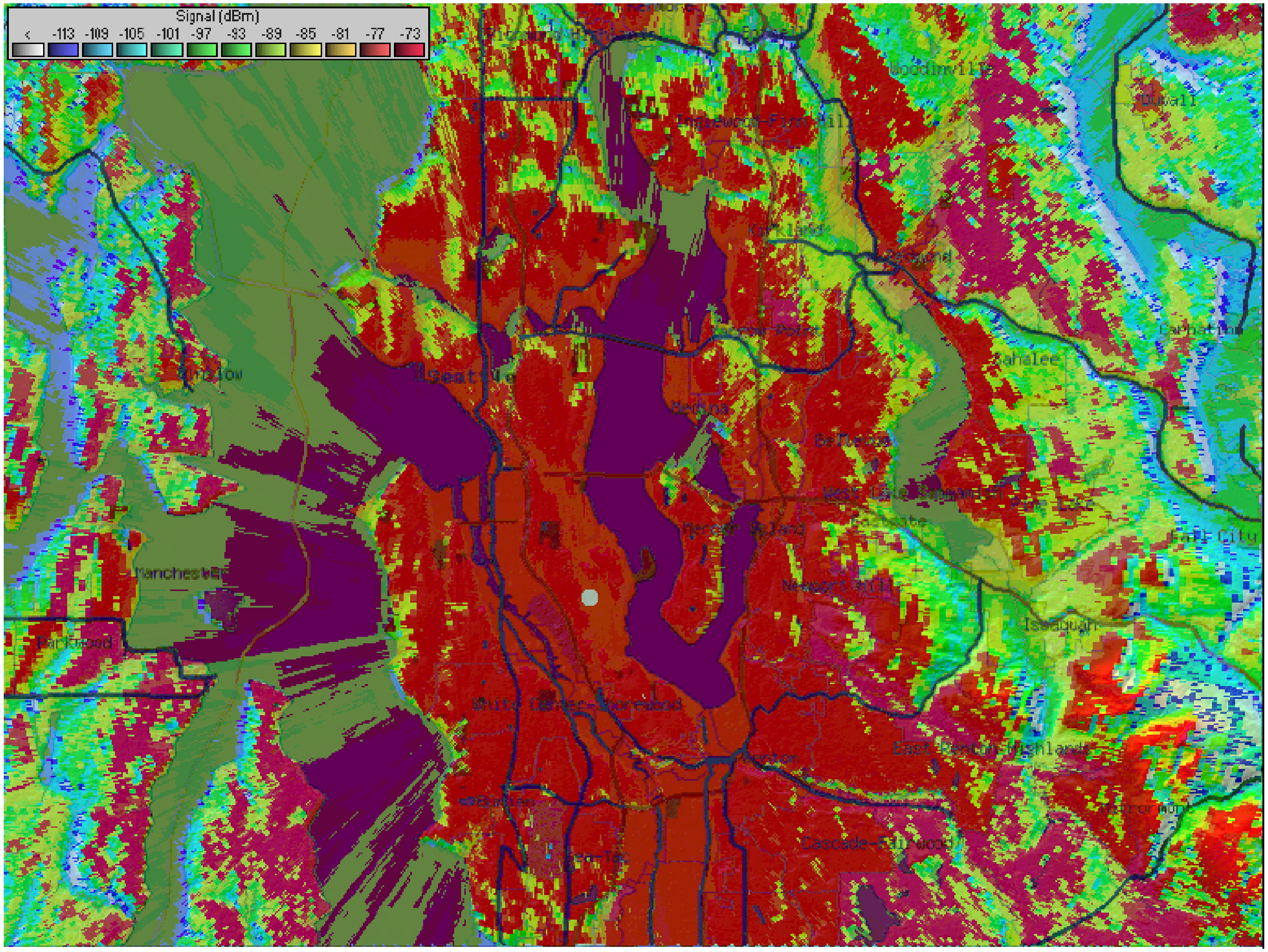
W7SRZ Coverage Plot



Area covered is 1017 square km

47°35'33"N 121°59'37"W 135m

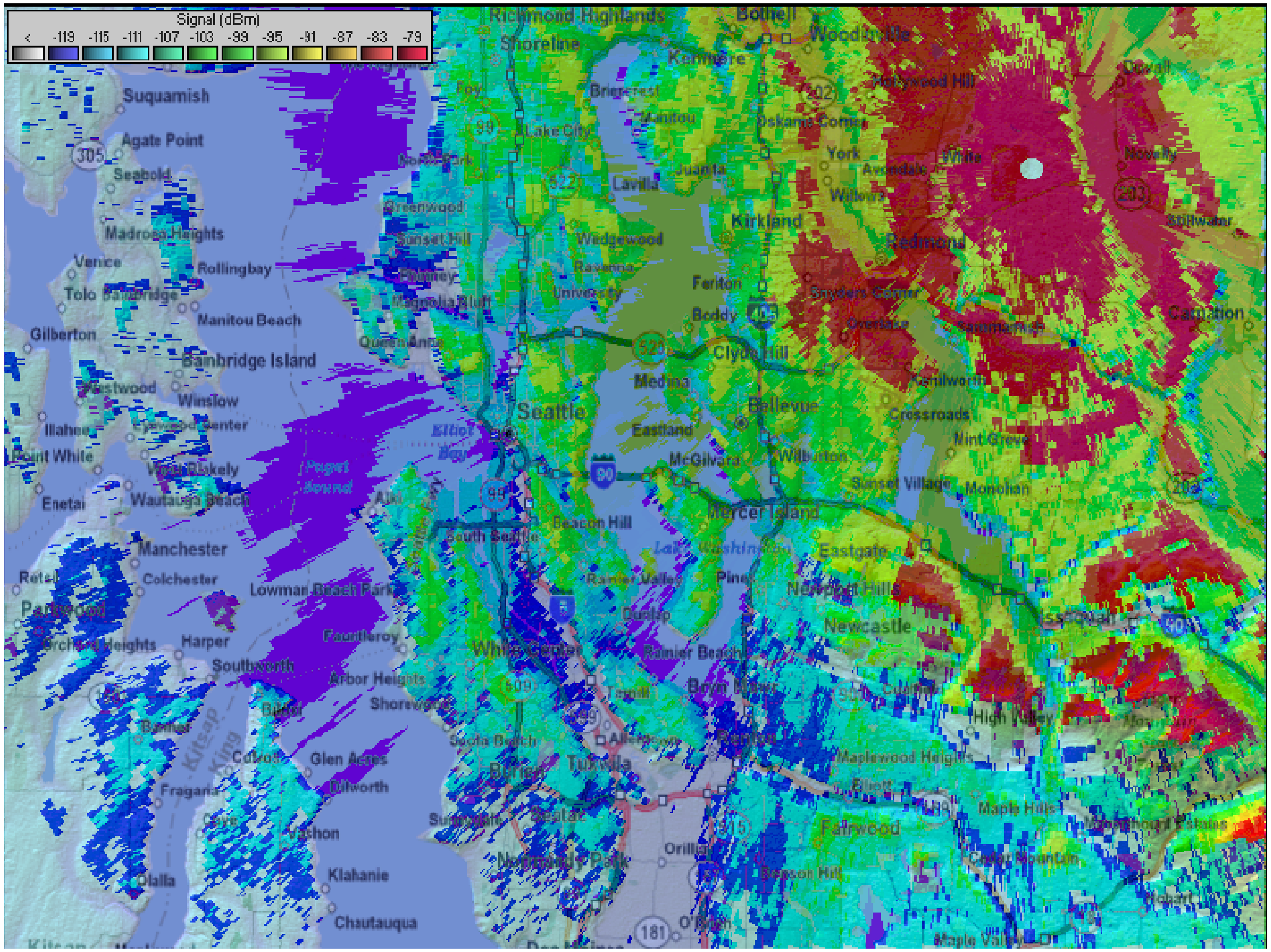
W7SRZ Coverage



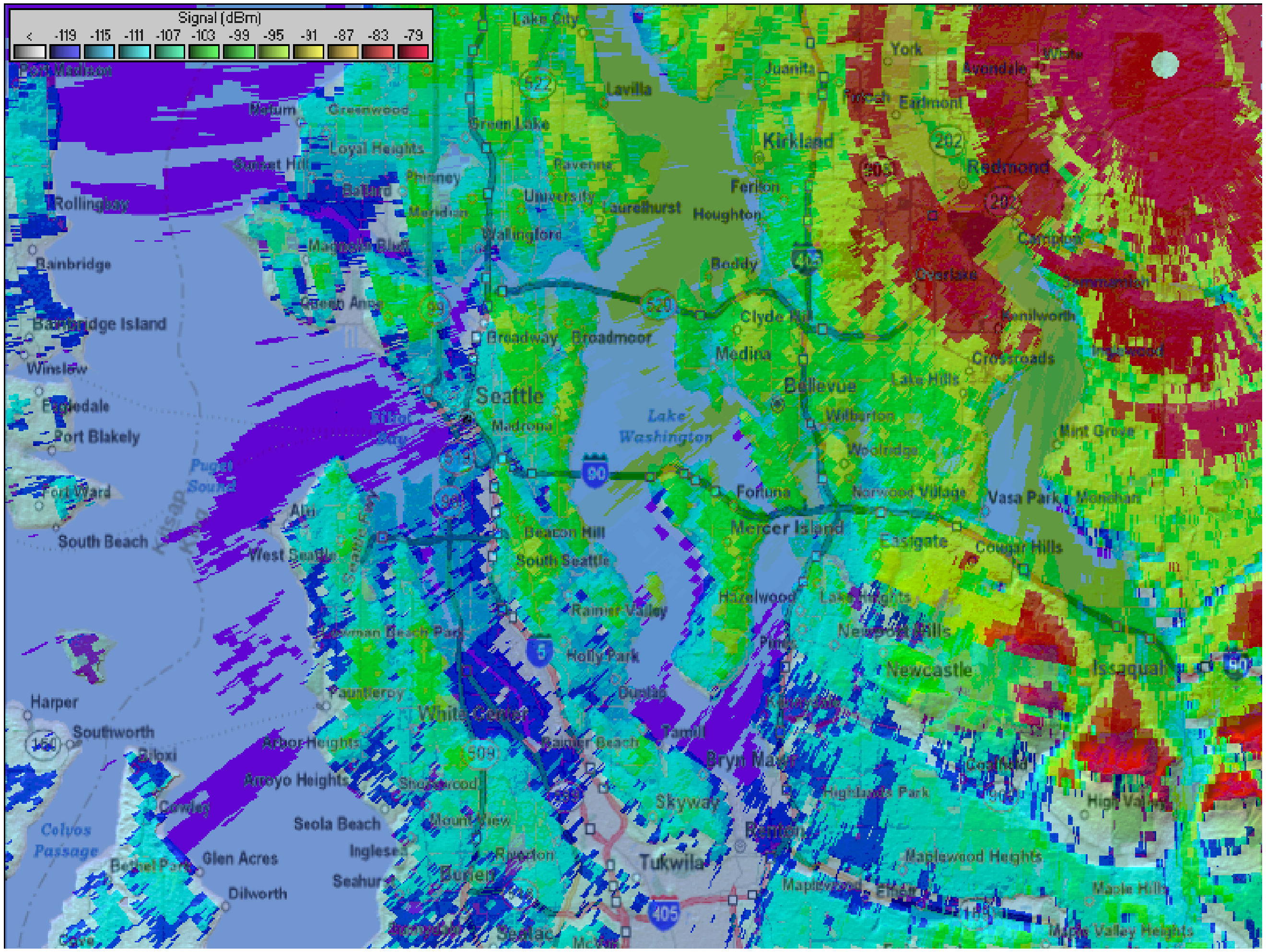
RF Coverage Plot

- Under the Plot dialog select all three options
- Choosing Rainbow coverage will show you areas of varying signal strength which can be very useful
- Change Threshold to read dBm and change "From" to -73 and "To" to -43
- Check to make sure the omni.ant antenna pattern file is selected and then click on Apply
- Click on yes when asked to convert the map to grayscale

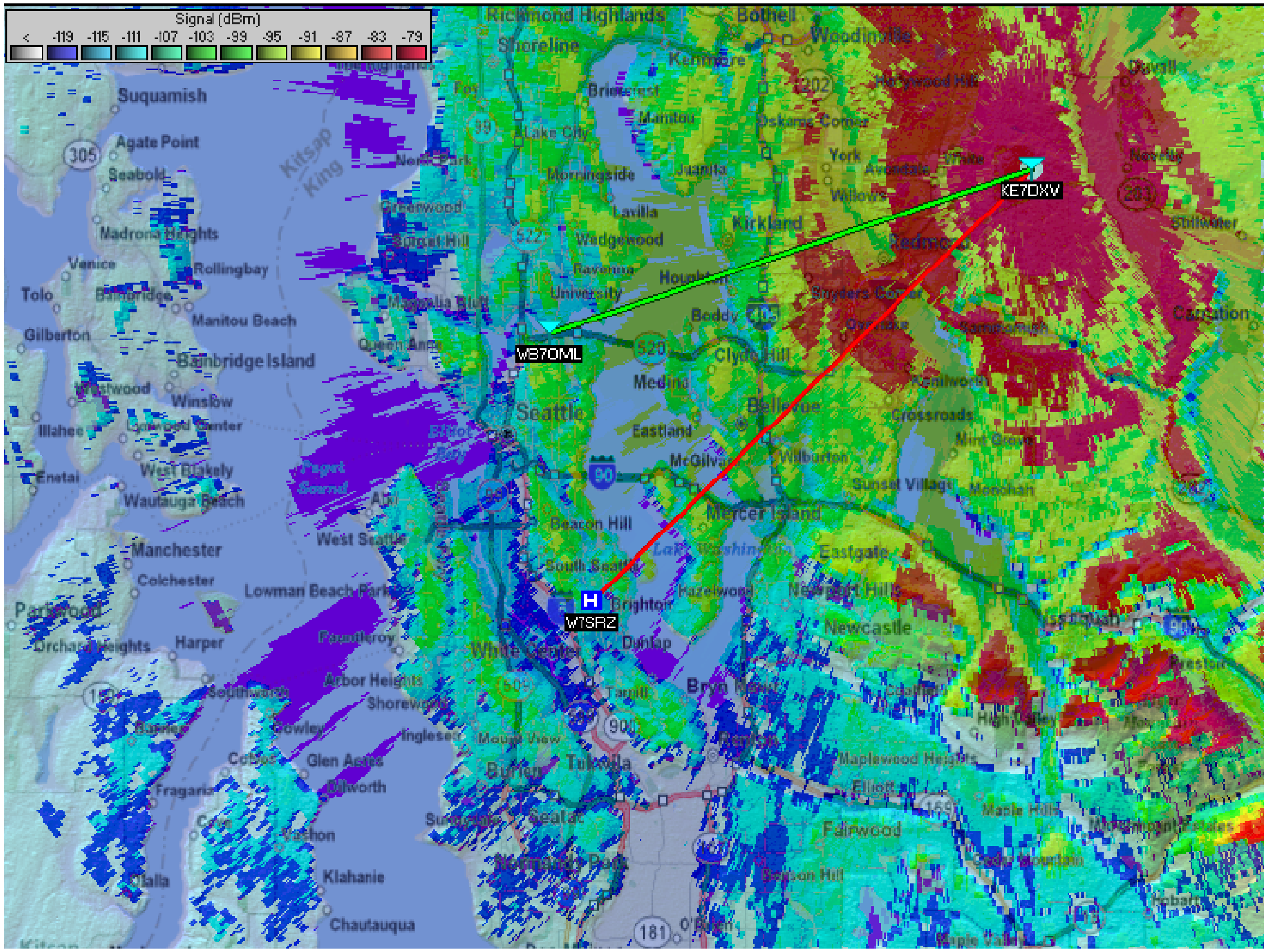
Redmond Ridge Tx at 5 watts



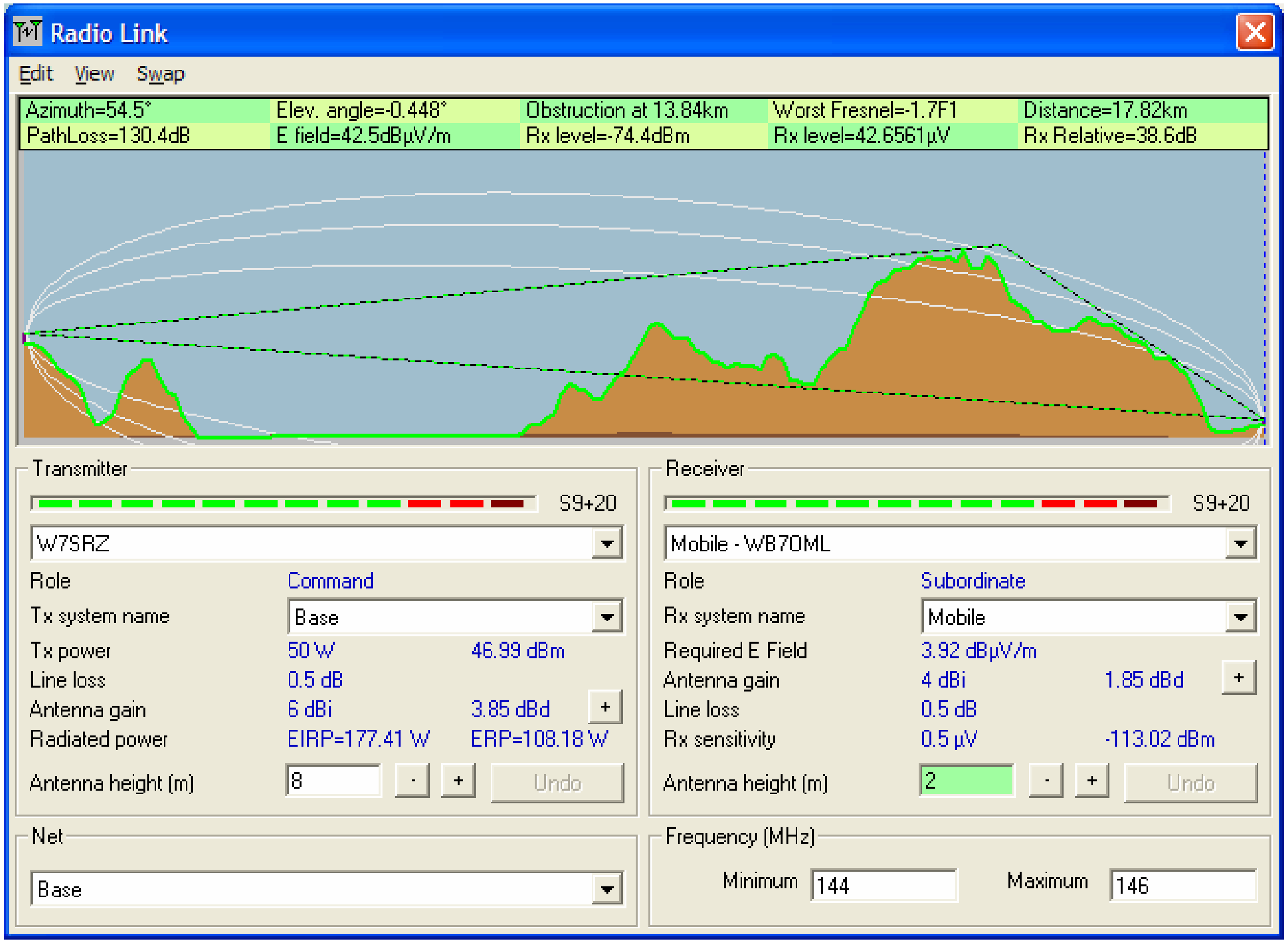
Redmond Ridge Tx at 50 watts



Redmond Ridge 50 watts YAGI



Radio Link Path Modeling



Azimuth=54.5°	Elev. angle=-0.448°	Obstruction at 13.84km	Worst Fresnel=-1.7F1	Distance=17.82km
PathLoss=130.4dB	E field=42.5dBµV/m	Rx level=-74.4dBm	Rx level=42.6561µV	Rx Relative=38.6dB

Transmitter

S9+20

W7SRZ

Role	Command	
Tx system name	Base	
Tx power	50 W	46.99 dBm
Line loss	0.5 dB	
Antenna gain	6 dBi	3.85 dBd
Radiated power	EIRP=177.41 W	ERP=108.18 W
Antenna height (m)	8	

Receiver

S9+20

Mobile - WB7OML

Role	Subordinate	
Rx system name	Mobile	
Required E Field	3.92 dBµV/m	
Antenna gain	4 dBi	1.85 dBd
Line loss	0.5 dB	
Rx sensitivity	0.5 µV	-113.02 dBm
Antenna height (m)	2	

Net

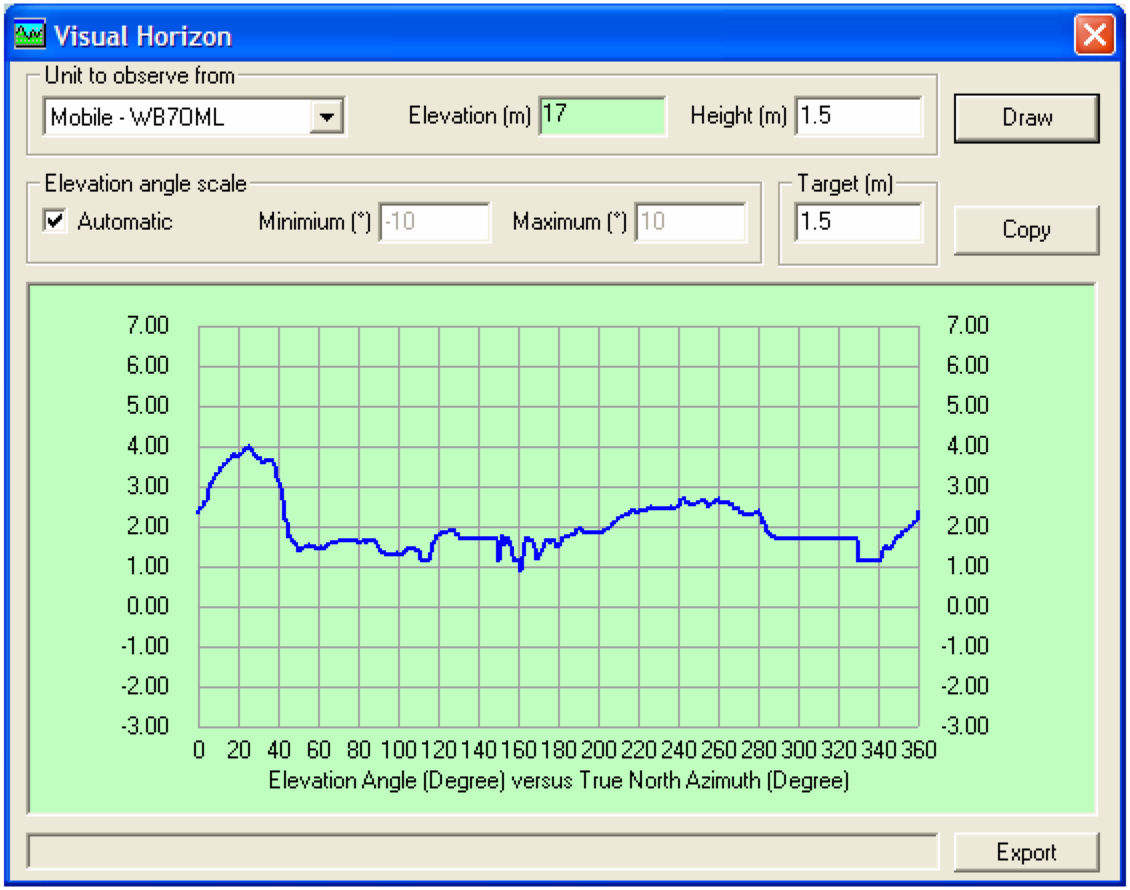
Base

Frequency (MHz)

Minimum 144

Maximum 146

Visual Horizon



Visual Horizon

Unit to observe from: Mobile - WB7OML

Elevation (m) 17

Height (m) 1.5

Elevation angle scale

☑ Automatic

Minimium (°) -10

Maximum (°) 10

Target (m) 1.5

Summary

- This was only a basic introduction
- Radio Mobile has many features
- Download it and try it!
- Browse websites to get a feel for the features and capabilities
- Sign up to the YAHOO! group

References

- Download Radio Mobile software at:
  - **http://www.cplus.org/rmw/english1.html**
  - http://www.g3tvu.co.uk/Radio_Mobile.htm
- Radio Mobile YAHOO! Group
  - **http://groups.yahoo.com/group/Radio_Mobile_Deluxe/**
- Advanced Information:
  - A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode (NTIA REPORT 82-100)
  - **http://www.its.bldrdoc.gov/pub/ntia-rpt/82-100/report_no_appendix.pdf**